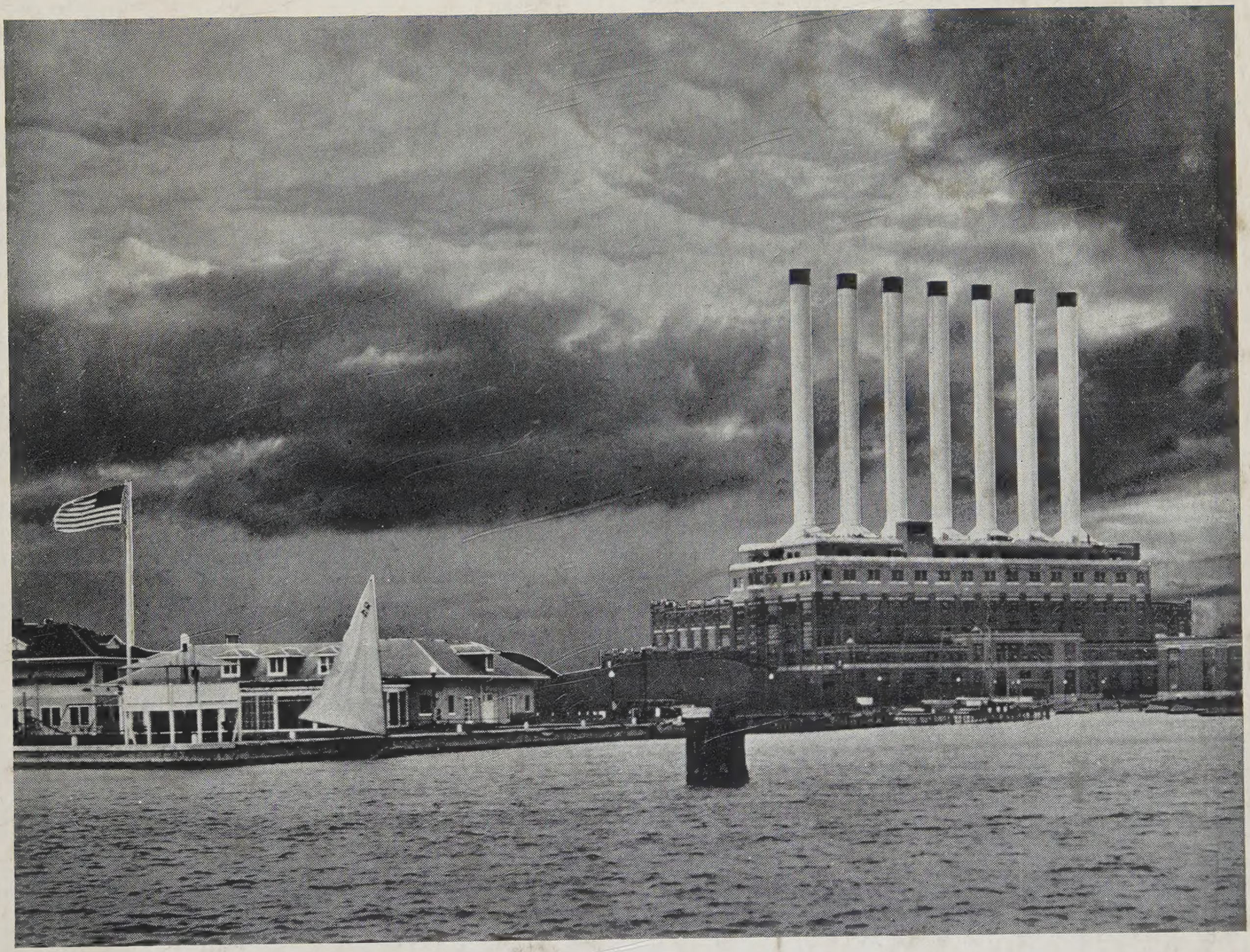
Electrical Engineering

July
1933



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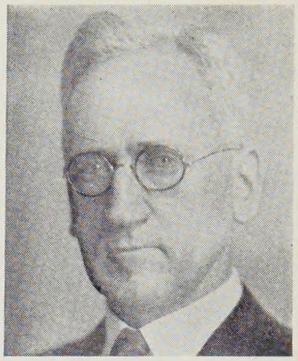

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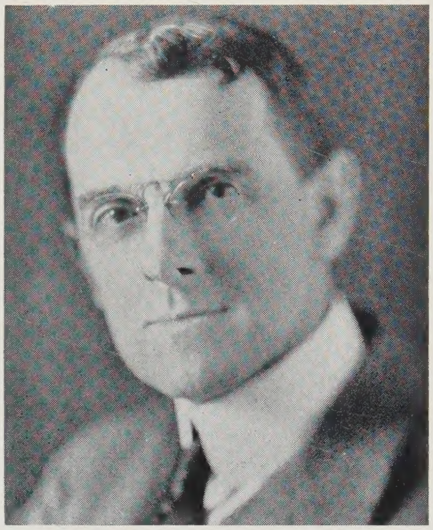

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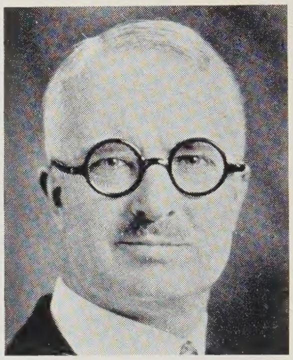

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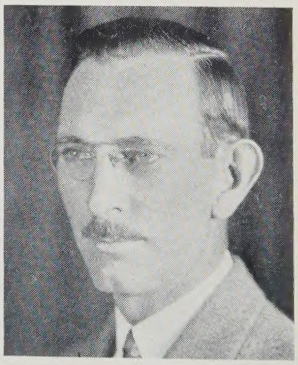

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This Month—

Front Cover

An afternoon view of the Connors Creek Power House of The Detroit (Mich.) Edison Company, located on the Detroit River. On the left is the Detroit Edison Boat Club, maintained by and for employees of The Detroit Edison Company.

Photo Courtesy Detroit Edison Synchroscope

—Turn to Next Page

POWER FACTOR and total oxidation products for individual layers of paper tapes of service aged cable insulation have been investigated in a study of the deterioration of 24-kv power cables. Oxidation due to leakage of air into and along the cable was found to be the major cause of deterioration of solid type cables in service. *p. 450–4*

PRACTICAL methods have been developed for metering high voltage loads on the low voltage side of power transformers, using a compensating meter in combination with a watthour meter. As well as resulting in a saving in cost, accuracy is equal to or better than high voltage metering. *p. 454–61*

RECENT improvements have been made in the design of sectional mercury arc rectifiers. These have been incorporated in a 4-section rectifier rated 3,000 kw, 625 volts, being installed for the independent subway system of New York City. *p. 462–6*

DEVELOPMENTS in the generation of electric power during the past 2 years are presented in the report of the A.I.E.E. committee on power generation. General trends in steam plant and hydroelectric plant practice are outlined and future possibilities discussed. *p. 488–503*

HEAT radiated from the human body can be controlled by radiation from electrically heated walls. Temperature of the air can then be lowered and a remarkably uniform temperature within the room is secured. *p. 467–71*

INCREASED complexity of high speed transmission line relays makes low voltage testing more difficult. As a result, staged tests involving an artificial short circuit on the high voltage line have many advantages. The procedure in making staged tests has been carefully worked out. *p. 471–4*

ELECTRICAL shock causes muscular contraction of the heart and if heart action is not stopped entirely, fibrillation may be induced. Experimental work has demonstrated conclusively that normal rhythmic functioning can be restored in many cases by the application of a high voltage countershock. *p. 475–7*

FUEL consumption of an existing generating station has been considerably reduced by the installation of a new boiler and high back-pressure non-condensing turbine which exhausts into the present turbines. Included in the electrical and mechanical changes are a supplementary oil burning system and the welding of pipe joints. *p. 481–6*

LETTERS to the editor continue to be submitted by members and cover a variety of interesting topics. *p. 509–11*

THROUGH continued research, substantial progress has been made in mitigating the damaging effects of lightning on electric power lines. *p. 448–9*

AWARD of prizes for Institute papers to 3 members of the Institute has been made by District 8 for papers presented during the calendar year 1932. *p. 504*

DISCUSSIONS of the papers presented before the Schenectady, N. Y., meeting of the Institute, May 10–12, 1933, are summarized in this issue. *p. 506–08*

MINUTES of the annual meeting held on the opening day of the Institute's 49th summer convention, Chicago, Ill., June 26, 1933, are outlined in this issue. *p. 504–05*

ANNOUNCEMENT was made of the election of 6 distinguished men to honorary membership in the Institute at the annual meeting held in Chicago, Ill., June 26, 1933. Only 9 other individuals hold the grade of Honorary Member, highest in the Institute. *p. 505*

LARGE numbers of carrier telephone circuits can be obtained from cable, as proved by experiments on an extensive installation of a 25-mile loop of underground cable. Satisfactory transmission quality and adequate prevention of interference may be secured. *p. 477–81*

DISCOVERY of X rays was made 33 years ago; however, their nature remained unknown for 17 years. Now, they are useful in medical diagnosis and in the examination of industrial materials; they also are important in the biological field and in physical science. A popular discussion of X rays is presented in this issue. *p. 486–7*

FORMAL presentation of the Institute's Lamme Gold Medal for 1932 was made to Dr. Edward Weston at the annual meeting, Chicago, Ill., June 26, 1933. Another Institute member, N. W. Storer, has received another Lamme Medal, this one awarded by the Society for the Promotion of Engineering Education. *p. 504*

The Engineer and A Century of Progress

Emphasizing the effects of science and engineering upon the life of man, and the basic need for a better understanding of these effects throughout human society, President Charlesworth in addressing the annual summer convention at Chicago urged engineers to take a greater part in all affairs affecting human welfare. That the message may reach the entire membership, the full text is published herewith.—The Editors.

By
H. P. CHARLESWORTH President A.I.E.E.

WE ARE gathered here at Chicago this week not only to participate in our usual summer convention, but also in a coming together of the greatest conclave of engineers of our own and other professions that ever has assembled or that may assemble again for many years to come. The occasion of this assembly is in a sense a celebration of a century of progress so admirably portrayed by the wonderful monument to human advancement that has been spread out along the shores of Lake Michigan, through the courageous efforts of the people of Chicago in honor of the centennial of the incorporation of Chicago as a village.

It is an interesting coincidence to those of us who are electrical engineers that electrical science is approximately the same age as the City of Chicago. It was just 100 years ago that Faraday in England, Henry in the United States, and other great scientists building upon the work of Ohm, Ampere, Oersted, and others, were completing the foundation of fundamental principles upon which have been erected the vast fabrics of applied arts and industries which are the concern of the electrical engineer today.

The wonderful exhibition here in Chicago, aptly termed "A Century of Progress," presents the progress of man during the past century in particular. It is most fitting, therefore, that we should find here gathered together engineers and scientists from all parts of the world, especially when we recall the great contributions to this progress made by them individually and collectively. What is more important, however, is that we are, I believe, consciously or unconsciously, carefully weighing the progress which has already been made to the end that we may gain courage to carry us through our present difficulties and inspiration to plan for still greater achievements in the future, not alone in the material things of life, but also in the broader aspects of human advancement.

During the past 50 centuries or so of historical time and throughout the unnumbered centuries that preceded them, the story of mankind has been primarily a struggle for existence. We need go back only a comparatively few years to observe the scarcity of machines and mechanical aids that were available. Indeed, using his hands alone, the average man had to work from early morning often far into the night merely to provide food, clothing, and shelter. Today, this average individual has material comforts that not so long ago would have been the envy of the favored few.

Surrounded as we are with safe and comfortable modes of living, it is difficult to appreciate adequately the status of mankind during that earlier period. Yet, it is essential that we should vividly picture his trying existence if we are fully to appreciate the degree of our progress and the relative unimportance of some of the hardships resulting from our present difficulties. To draw our comparison properly we must study carefully the life of the masses of people in the earlier centuries, and thus secure some picture of the hardships of living, often in isolation with no ready means of transportation or communication, with heat and shelter depending upon the crudest facilities, sustenance often on single crops subject to the vicissitudes of the weather; with life as a whole frequently controlled by the whims of a despot or warring factions. An existence, therefore, for the average man much like that character in Grecian mythology who, in the Lower Regions, was condemned eternally to roll the stone of forlorn hope up the steeps of despair.

How different the picture as we contrast these earlier conditions with our present state of civilization, and contemplate what has been accomplished in improving our existence and removing drudgery from our daily tasks. We cannot fail to recognize, therefore, that, during the past century in particular, science more than any other single factor has influenced human affairs and added to the opportunities for a broader and happier life.

In spite of this evidence on every hand of real benefit which mankind has secured through the progress of science and engineering, we occasionally find arising in some quarters, and particularly under the difficult times through which we have passed, a fear of science and its effect upon us. We hear that there should perhaps be a holiday in the field of research and in the new applications of science. To any intelligent and thoughtful person it is evident how foolish and vain both these points of view are and I think we may view with satisfaction the fact

that we have been in no way influenced by these false premises, but rather that we have adhered steadfastly to the sound principles upon which our progress has been based.

We know full well that we cannot set up arbitrary or effective bars against man's curiosity of the unknown, or the researches which follow from that curiosity, nor can we long delay the introduction of things which man believes to be valuable additions to his social life. Furthermore, from our own experience, we have seen ample evidence, and there are constantly spread out before us many examples of the fact that such advances should not be retarded but on the contrary, are the very instrumentalities upon which our future progress must be based.

It is true, of course, that we have been passing through difficult times and have experienced during the past 20 years 2 of our greatest catastrophes, namely the World War and the present world-wide industrial depression. We find ourselves today in a world which has experienced undue privation and want, full of anxiety and uncertainty, and here and there in actual discord. Perhaps it is not surprising, therefore, that some have questioned: "Has this really been a century of progress?" However, I am sure that there is ample proof that the present crisis from which we are emerging cannot wipe out the experience of a century of lessons or the real measure of our progress which is to be derived therefrom.

Progress is defined as "a moving or going forward, an advance toward better or ideal knowledge or condition or that conceived of as better." In other words progress is an advance toward a goal and in order to determine whether or not progress is being made, it is necessary first to define our goal. I believe that there is general agreement that the goal toward which mankind is striving is an increase in human happiness in its broadest sense. Our goal remains poorly defined, however, until we express in some more concrete way the conditions that are expected to lead to the greatest happiness of all mankind. One would be bold, indeed, to attempt a detailed definition of this matter which has to do with so many factors concerning the whole relationship of man to man and of man to his environment. May I venture, however, the suggestion that this involves primarily three things: first, the easy provision of the necessities of life, including among necessities the things commonly used by the social group; second, a sense of security obtained by minimizing the number and extent of those catastrophes which destroy or disrupt human life; and third, the capacity and opportunity through leisure for appreciation of the world and of the people and things in it, with the development of character and culture.

Now I think, particularly in view of the history of recent years, it must be admitted that the progress made in the last century, as thus broadly defined, has by no means kept pace with technological advances. The applications of science have opened opportunities for increased comforts, for decreasing the number of hours of labor required for producing the necessities of life, and for providing the surplus productivity which should lead to security and give men the leisure in which to develop and exercise the capacity of appreciating the world in which they live. As I see it, the difficulty is that these rapid developments in the material things of life naturally require the continuous adjustment of society, and up to the present time social reorganization has not kept pace with our material advances.

This is not a condition of recent years alone. It appears to have been a chronic condition of society. It involves many factors, among which is a lack of appreciation of what science is accomplishing for mankind. This can be illustrated in many ways, as for example, by the opposition with which many important advances have been greeted, particularly in earlier days. Developments that are evidently of great benefit to mankind, in one way or another, repeatedly have been opposed even by those who should be in the best position to realize the ultimate advantages of the new device. We smile when we read a 17th century protest against the "large coaches" which were about to be placed in service between London and York and which would carry as many as 18 passengers and would make the trip of 175 miles in 4 or 5 days. We note "the vast amount of employment those eighteen persons would give to grooms, farriers, innkeepers, hostlers, saddlers, etc., if each were to rise his own horse instead of adopting the revolutionary practice of clubbing for a common conveyance." Again, we recall with interest, that when attempts were made to introduce the saw mill in England they were opposed violently; yet we know that soon it became recognized that through its use human effort could be conserved, new products looking toward human comfort could be provided at reasonable cost, and through the diversity of the mill the opportunity for employment actually be increased. And so might be cited similar examples in every phase of our industrial progress. Fortunately, with a growing understanding of what science is accomplishing there has been less opposition and material progress has been possible but other serious problems have presented themselves.

While, therefore, any well considered study of our advancement particularly in the past century, cannot but lead to the conclusion that science and invention have been the life blood of our progress, it must be recognized that during this period science has injected into human life a multitude of factors with which our forefathers did not have to deal, but with which we and our successors must reckon. The sooner we approach a better understanding of these factors and how to deal with them in an intelligent and forward-looking manner, the sooner will we make for real progress in the broader problems that confront us. In other words, we must recognize and understand these new factors so as to weave them properly into our social structure. The application of science is placing in the hands of individuals, and of nations, vast powers for good or evil, far greater than those of any earlier century. Hence, the pace of humanity, in any direction in which it is advancing, constantly quickens. With this has come an increase in the complexity of social relationship brought about through a closer and closer interdependence of the different parts of the world.

All this, it seems to me, must have an important

bearing on the work of the engineer. In the earlier days, we find the scientist and the engineer working in a large measure in isolation, and working, in turn, on the many phases of a problem often not too well defined. As time progressed, and to an increasing extent during the past century, we have found large groups coming into existence for the study and furtherance of research and engineering. Today the modern research or engineering problem is being approached by a group attack; that is, the problem is being defined as far as practicable and specialists in their respective fields are being assigned to its various parts. And so we find the engineer depending to a greater and greater extent upon his fellows, not only in his own profession, but also in the other branches of the arts and sciences. Not only is this true in industry itself, but in order that their work may be carried on effectively and to the end that they may be qualified and keep in step with the rapid progress experienced particularly during the last half of the past century, engineers have had a greater and greater tendency to come together into great organizations such as our own society. In more recent years we find a growing recognition that not only must we be banded together in our own profession, but there must be a growing tie between engineers generally. Thus came into being the American Engineering Council and similar organizations which already have done so much for the profession and for the nation.

As I view the situation, however, these activities alone will not be sufficient. We must be prepared to take an even greater part in public problems and to assist in the affairs of society generally through daily contacts as citizens of our communities and of the nation. In some respects the engineer seems to me to be in a position to make a special contribution. He should have a clear perception of the nature of the revolutionary technical changes through which the world is going, of their effect on human life and on the social problem. Furthermore, if he has, as he should have from his training, developed the scientific habit of thought, that is, approaching the problem from the standpoint of determining the facts and reasoning from those facts to the conclusions, he should be able to bring something of real value to bear upon the problems of social reorganization. He has come to realize through years in the hard school of experience that things cannot be taken for granted, that the best way of doing a thing today may be far from the best way of doing it tomorrow.

The social problem involves all the people and its solution requires the continuous effort of men of all vocations who can contribute to it. As I see it, therefore, in embarking upon our work of the next century we should find the engineer not only working in closer association with his fellows in the field of science and engineering, but, if he is to prove of greatest usefulness, also developing a closer association with other groups of society. To the extent that we effectively recognize these new responsibilities and opportunities, we will, I am sure, make still greater contributions to the benefit of mankind. As we enter upon these broader responsibilities of our profession, we should proceed with characteristic purposefulness, always remembering, however, that in many cases our greatest help can be by contributions within the limit of our knowledge and experience, rather than attempting alone to direct in fields where considerations beyond the scope of engineering must weigh heavily in the final decisions.

Opportunities for constructive help present themselves on every hand, particularly in times like the present. Basically there is need from the very beginning for a better understanding of the effects and results of science and engineering on our daily existence. We who have made this our life work are, it seems to me, in the best position to foster a real understanding of what science is and what it reasonably can be expected to accomplish or not accomplish and the methods by which those results can be employed most effectively. This greater knowledge is necessary not only to scientists and engineers, but also to those who make up society generally. It seems to me, therefore, that this becomes one of our fundamental responsibilities.

To appreciate the importance of the broader understanding, we have but to look about us and consider what has been going on in many fields where a full recognition of the effects of science has not been taken into account. Despite the rapid progress that has been made and the marked effect which new developments, that can often be foreseen, may have on products or procedures, we often have seen planning and financing carried on year after year without a recognition of the effects which these rapid changes have on industries or individual projects in question. In many industries based on science it has been found to be as important to know about their research or engineering organizations and of the attitude of the management toward these activities as it is to know about their financial status. Again, in the case of agriculture for example, we often have seen efforts being directed toward greater and greater production of a given product of the soil when overproduction as a whole already was in evidence. Too many great undertakings have been carried forward without reflecting adequate advance planning; and conversely, other projects that have had a full measure of such consideration devoted to them stand out as marked examples of the value and importance of such an approach.

Not only can the engineer be helpful in those matters in which his profession is directly concerned but also in the broad problems which today confront our nation and the world. Many of these do not involve engineering matters, but nevertheless do require the same careful planning and foresight which enter into our daily engineering undertakings. If, in our individual capacities as good citizens, we can apply some of this attitude of mind and instill in others the importance of this approach to some of these problems, I am confident we can make contributions of great value in these broader fields as we have in the fields of science and engineering. The need for some such approach to the problem is all too evident when we consider some of the spectacular proposals which, although based on such an utter disregard of fundamental facts, are submitted from

time to time as cure-alls for the troubles of the world.

Gradually through a general understanding of science and the application of the principles of straight thinking to some of our broader problems, we should be able to make progress in the field of social organization as man has in the material aspects of human advancement. That we should be able to make this broader progress, I believe there can be no doubt, for, in the recent words of President Roosevelt, "Certainly the human intelligence that has accomplished the industrial and cultural results displayed at your Exposition need not fall short of devising methods that will insure against another perilous approach to collapse such as that from which we are now emerging. . . . . . The advance of science and the evolution of humanity and charity made it known to us that whatever is the result of human agency is capable of correction by human intelligence. Who is there of so little faith as to believe that man is so limited that he will not find a remedy for the industrial ills that periodically make the world shiver with doubt and terror?"

As I have indicated already, there is opportunity for the engineer to make substantial contribution to the advance of this side of our social welfare. That he may prepare himself to take this broader responsibility, he must, as I see it, adjust himself to an even broader viewpoint, and acquire a more intimate knowledge of the economic forces and social problems of our daily life, than he has in the past. That he will be able to do so I have no doubt. As our engineering educators so wisely have appreciated, this trend also must be fully reflected in the training of the younger men who are to become the leaders in the future. If we thus can make progress toward a better equilibrium between our technical and social knowledge and reflect its effect upon the advancement of society generally, then I believe we may look with real hopefulness to a nearer approach to our goal of progress as previously interpreted.

The development of culture requires leisure from the struggle for existence, and such leisure gives us opportunity in turn for the development of things of the mind and of the spirit. At various times in history, periods of culture have been experienced. Often, however, this has come about through opportunity for leisure for the few by imposing drudgery on the many. Can we not look upon science, however, coupled with a proper utilization of the products of science, as the medium through which we now may secure a reasonable degree of leisure for the greatest number? With this, no doubt, comes the added advantage of tending not toward lack of initiative coupled with that leisure, but toward creation of leisure through initiative itself. May we not then feel that we have really built on a firm foundation for progress?

If we of the engineering profession, working in full cooperation with all other groups of society, can contribute in some measure to this further progress of mankind, we may justly take pride in the service we render and feel with satisfaction that again we have widened our sphere of social responsibility. Society, I believe, has come to expect of us a devotion to the truth wherever the facts may lead us and an aim toward unbiased judgment. We should safeguard this trust which is placed in us and continue our efforts along those channels of endeavor wherein we may be of greatest help, and in those fields where we are best qualified to advise, to the end that we always may be of greatest service to society as a whole. If we can so govern our efforts in the period ahead and broaden our knowledge and approach to a better molding of the social and material sides of life, we will have done our part in making the world a better and happier place for our fellowmen and will reap the satisfaction that comes to all of us from worthwhile endeavor.

The Romance of Lightning Research

In this brief discussion Mr. Lee in his characteristically interesting manner outlines what engineers have accomplished in mitigating the damaging effects of lightning on electric power transmission lines. Although all problems have not yet been solved, substantial progress has been recorded.

By
EVERETT S. LEE
FELLOW A.I.E.E.

General Elec. Co.,
Schenectady, N. Y.

IN STUDYING the papers for the 1933 A.I.E.E. winter convention, with particular references to the symposium on insulation coordination, the session on lightning, and the session on the measurement of surge voltages, one is impressed by the great difference between the situation today and in 1925, which may be taken as the year when began the last romance with lightning by electrical engineers.

That was the year of many storms, made memorable by the wreck of the dirigible, "Shenandoah." In that year occurred the troubles described by Sindeband and Sporn in the first paper of the series of which Mr. Sporn has presented another. ("Lightning and Other Experience With 132-Kv Steel Tower Transmission Lines and Its Bearing on Tower-Line Design From the Continuity of Service Standpoint," A.I.E.E. TRANS., v. 45, 1926, p.

A discussion of papers on "lightning" presented at the A.I.E.E. winter convention, New York, N. Y., Jan. 23–27, 1933. *Not published in pamphlet form.*

770–90.) In that paper the authors say in their characteristic way:

"While these troubles were occurring, it was impossible to get any accurate data as to what was happening. Lines were flashing over, insulators were being shattered, the conductor was being burned, the field forces were too busy trying to place the line in an operating condition with minimum delay to be able to give very much attention to the details of what was happening. Things were happening so thick and fast that there was no opportunity to stop and consider the matter calmly. With the approach of the end of the lightning season a little more time could be taken to determine what had actually happened to make an intelligent analysis."

This graphic description undoubtedly finds a human response within all who at one time or another have found themselves in the midst of kindred troubles.

Coincidently with the need for analysis, which was evident generally, came the necessary tools, for in the A.I.E.E. TRANSACTIONS of 1925 may be found a paper ("The Klydonograph and Its Application to Surge Investigation," v. 44, p. 857–71) delivered by Cox and Legg at the 1925 summer convention, Saratoga Springs, N. Y., telling of the klydonograph and the use of Lichtenberg figures as a means for measuring surge voltages. At the same convention, McEachron and Wade gave their paper ("Study of Time Lag of the Needle Gap," A.I.E.E. TRANS., v. 44, 1925, p. 832–42) describing the application of the cathode ray oscillograph to time-lag studies of spark gaps technique in the same field.

Then started the romance of the engineers with lightning, and the wooing was furious. Out into the field they went on many different systems—east, west, north, and south, equipped with devices advancing year by year. Klydonographs and surge voltage recorders were dotted thickly along transmission lines to measure the voltages there. Up went the recorded voltages—1 million, 2 millions, 3 millions, 5 millions. The cathode ray oscillograph, laboratory instrument of the scientists, was taken out into its mountain home to await the coming of the lightning which the observers prayed would come in abundance and which the operators prayed would stay away with its devastation. But it did come and the cathode ray oscillograph, waiting, revealed the wave form of the voltages measured by the surge voltage recorders. This brought microseconds into the picture and engineers talked glibly on one microsecond and 10 microseconds, while yesterday and today standardizations of these values are discussed with no more hesitation than the standardization of volts and ohms and amperes and degrees.

The romance continued. With the measurements of lightning voltages came the need for rating the severity of lightning, so the storms were counted, and the lightning severity meter was devised and used. Then came the wish to know more about the currents involved, and the lightning stroke recorder was developed; more instruments appeared along the transmission lines; talk of 50,000 and 100,000 amperes became common. Coming now to the 1933 winter convention, in the paper by Lewis and Foust ("Lightning Investigation on Transmission Lines," A.I.E.E. TRANS., v. 52, June 1933) is found an intensive study of the tower currents from lightning stroke recorders and a new instrument referred to, the surge-crest ammeter (*G. E. Rev.*, v. 35, 1932, p. 644–8) used for an extension of that work.

With the gathering of all these data and the intensive analysis accompanying them, transmission engineers began to talk of new schemes; the counter poise came into the picture to supplement the ground wire; lightning protection wires appeared; and through it all, the ground wire of old rode safely through the storm, being rendered even more effective by these devices.

New words came into prominence—rationalization and coordination—and now these are subjects for standardization. Direct strokes and induced strokes became subjects of conversations, papers, and discussions; today the knowledge of these is more certain, though apparently not yet subjects for standardization.

Turning again to the experiences recorded by Mr. Sporn, unlike those related in the 1926 paper, there is found in his 1932 paper ("Lightning Experience on 132-Kv Transmission Lines of the American Gas and Electric Company System," A.I.E.E. TRANS., v. 52, June 1933) these words:

"The fact that comparatively few insulators, burned conductors, or hardware have been observed, and rarely of sufficient importance to require servicing, shows that the arcing protection has been very effective in preventing severe damage to the line. The protection afforded by the rings to line insulators is in line with prediction and past experience.

"During the 3 years' operation, 1929–30–31, no trouble from lightning on the 132-kv lines has made necessary holding the line out of service longer than the time necessary to reclose the switch."

These are some of the results of the work which came after intelligent analysis. Of course, all problems have not yet been solved, but progress made toward that end is believed to be on a substantial basis.

In looking over some of the reports forming a basis of these papers, the following tabulation was found:

Year		Year	
1927	100	1930	100
1928	100	1931	70
1929	130	1932	50

No, these are not stock market indexes; they are storm severity records for one of the large transmission systems of the East based upon storm reports and line operation. Similar figures given by Mr. Sporn for his system do not show the same relative severity decrease in the last 2 years, even though his line performance record shows more satisfactory attainment. These data are a necessary part of the whole picture in order that proper credit may be given to the design of the line and associated apparatus throughout in view of the line performance. There is still much room for advance in the design of instruments for recording lightning severity, and though the problem is difficult, and the expense great, it is to be hoped that success in this regard ultimately will come.

Through all of this romance, there have been brought before many A.I.E.E. meetings and conventions the results of those who have worked so wonderfully and so effectively in this field. Their reward is their satisfaction of a work well done; at the same time due credit should be given the Institute which has made this forum possible.

Deterioration of 24-Kv Power Cables

The radial variation in electrical and chemical characteristics of cable insulation between conductor and sheath has been investigated by a new method whereby the power factor and the total oxidation products in the oil are determined for the individual layers of paper tapes. The results of this investigation applied to several types of service aged cable are reported in this article.

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FROM the time that an oil and paper insulated high voltage cable is placed in service underground a gradual deterioration of the insulation takes place which manifests itself in an increasing dielectric loss. Knowledge of the causes of the deterioration has appeared important because the increasing dielectric loss, besides representing an economic loss, is a threat to the service life of the cable. Little exact information has been obtained, however, because of the great difficulty attending the precise measurement of physical and chemical changes in the oil, rosin, and paper of cable insulation.

The conception that deterioration of the insulation occurs non-uniformly between sheath and conductor and that such non-uniformities might yield a clue as to the origin and nature of deterioration led to the development of 2 new procedures for measuring the electrical and chemical characteristics of aged insulation in a radial direction, layer by layer, from sheath to conductor. The first necessitated the design and construction of a cell for measurement of power factor of individual paper tapes. The second was the determination of oxidation products in the oil from individual paper tapes.

The power factor cell, shown in Fig. 1, consists of a heavy rectangular brass box 18 in. in length in which are mounted a high voltage electrode and a movable active electrode with guard assembly. Resistance heaters installed in the slotted sidewalls enable measurements to be made at elevated temperatures. Openings at the ends provide for the insertion of a cable tape folded in two. A stress of 50 volts per mil, a temperature of 60 deg C, and an inter-electrode pressure of 6.4 lb per sq in. have been adopted as standard. Readings require 2 min per tape. The instrument is rapid, accurate, and dependable, and is well suited to routine work.

The method of measuring oxidation products in very small quantities of oil utilizes the spreading characteristics of oxidized oils on a water surface, and is known as the hydrophil test. The oil is extracted from a few inches of paper tape by means of benzol. The spread of a given volume of the benzol solution is determined on an Adam's film pressure balance, and by determining the concentration of the benzol solution the percentage of oxidation products may be calculated. The method is extremely sensitive. The results agree far better with electrical measurements than those of acid number determinations.

With the aid of the methods mentioned above, some 30 samples, selected from 3-conductor 24-kv *H*-type cable, new and aged, have been investigated in a radial direction. All were impregnated with straight mineral oil unless otherwise stated. Typical results on service aged, acceleratedly aged, and new cables are given in Figs. 2, 3, and 4, respectively. No wax was found in any of the latter cables when they were dissected. The service aged cable was manufactured in 1927, and had been in service one year. A general similarity between the power factor and oxidation curves may be observed.

The curves of Fig. 3 were obtained from cable of 1930 manufacture. The sample tested was cut from the center section of a 45-ft length which had been on accelerated aging under continuous double operating voltage for about 2,700 hours. During the initial heating and cooling cycles a small amount of compound leaked from one pothead. The high values for oxidation products and power factor at conductor and sheath therefore might be explained

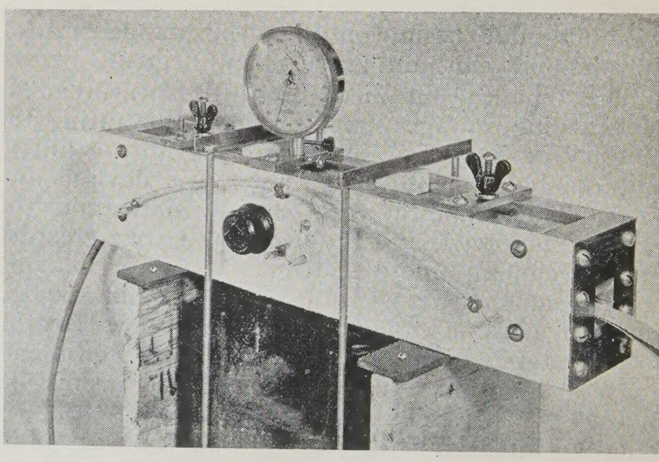


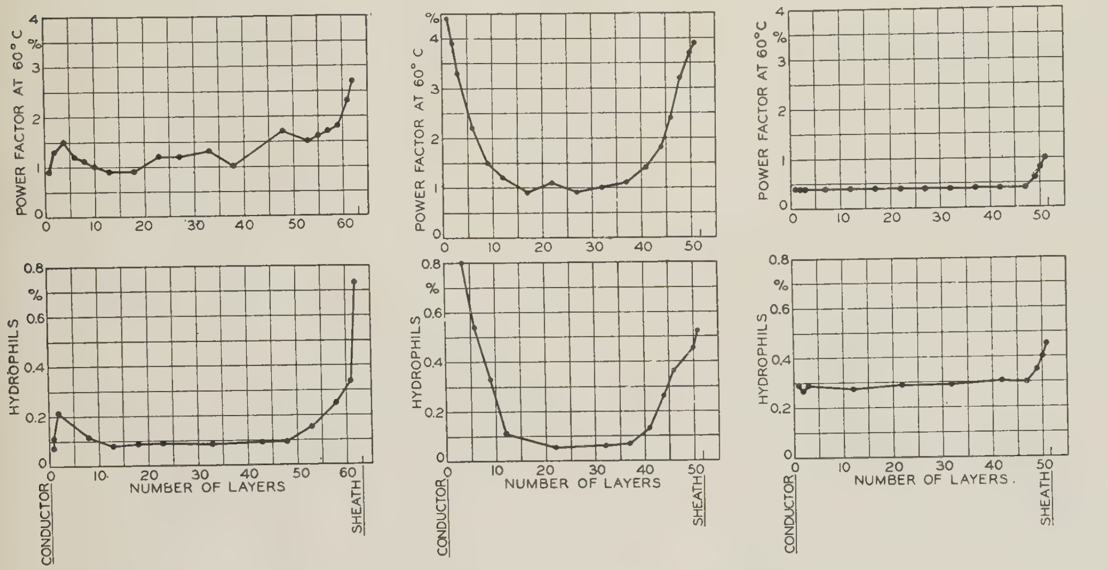
Fig. 1. Cell for measurement of power factor of paper tapes

Based upon "A New Method of Investigating Cable Deterioration and Its Application to Service Aged Cable" (No. 33-82) presented at the A.I.E.E. summer convention, Chicago, Ill., June 26–30, 1933.

on the basis of air leakage at the pothead, along the copper conductor and along the filler spaces, followed by radial penetration of the insulation.

In contrast to the results obtained with service aged cables, the radial power factor and hydrophil curves for new cable of 1931 manufacture (Fig. 4) are flat. From all these curves it is clear that deterioration of cable insulation in a radial direction is non-uniform, and that the form of the radial curves may give some clue as to the nature and cause of such deterioration.

In most cable samples all 3 conductors were examined for uniformity as to radial characteristics. *H*-type cable, a double U-shaped curve (one U-shaped curve for the core and another for the belt) has been obtained on the several samples so far examined as both power factor and hydrophil curves are plotted from conductor to sheath across the core and belt insulation. Both power factor and hydrophil values for the belt are lower than for the conductor insulation. This difference may be due either to the lower temperature which is experienced by the belt tapes, since the conductor tapes pass near to the center of the cable where the temperature is highest, or to the different grade of paper which is usually used for the belt insulation.



Figs. 2, 3, and 4. Power factor and oxidation products for individual layers from conductor to sheath

Fig. 2 (Left). A cable after one year in service
Fig. 3 (Middle). One core of cable laboratory-aged by load-cycle methods
Fig. 4 (Right). One core of new cable direct from the lead press

The results for the 3 conductors of a 1928 mineral oil cable aged one year in service are shown in Fig. 5. In addition to radial power factor and oxidation curves, the amount of wax present in the insulation is indicated as estimated by visual examination. In this case the hydrophil curves do not explain the power factor curves as well as in the previous examples given. The explanation appears to be that in addition to oxidation another aging factor is present, namely, ionization. This is borne out to some extent by the curves for conductor 1, where the least correspondence is apparent between hydrophil value and power factor, but where ionization as indicated by the wax deposits has occurred with considerable intensity uniformly from conductor to sheath. The effect of ionization appears to have been to raise the middle portions of the power factor curves for conductors 2 and 3 from about 1.2 per cent to about 2.2 per cent. In any case the general level of power factor of conductor 1, where wax is in abundance throughout the insulation, is higher than in the other conductors where no wax is present in the middle portion of the insulation.

It should be noted in Fig. 5 that the character of the deterioration is different in the 3 conductors. This observation is true for a number of other cables which have been examined.

The radial method has also been applied to cables of the belted type. Instead of the single U-shaped curve between conductor and sheath often found on

On older type cables, manufactured previous to 1920 and in service over 10 years, the power factor curves which have been obtained are roughly U-shaped, and of very high value. It is not unusual to find the 60 deg C power factor as high as 10 per cent at the lowest point and rising to over 15 per cent at conductor and sheath.

Discussion

There is little doubt that the hydrophil curves in Figs. 2 to 5 represent oxidation of the insulation. The question now arises as to the source of the oxygen. There are 5 possible sources: air left in the oil or insulation at time of manufacture, air drawn in at time of installation, air breathed in at porous joint wipes or at imperfections in the lead sheath during load-cycles, moisture due to imperfect drying which might be resolved by electrolysis, or the cable paper itself. Considering the paper first it might furnish oxygen to the oil in 2 ways, either by splitting off oxygen from the cellulose molecule through the agency of ionization, or by solution in the oil of lignins, resins, and associated materials which are present in small amounts in most cable papers. Experiments appear to show that cathode ray bombardment of oil impregnated paper in vacuum does not produce oxidation of the oil as a result of disruption of the cellulose molecule, but that the oxygen-containing materials such as lig-

nins, which are present in the cable papers, may be attacked and go into solution in the oil under bombardment. It is possible that under severe ionization they may increase the hydrophil content as much as one per cent. The effect of these materials is to promote oxidation of the oil when air is present, and probably to lower the resistivity.

Air occluded in the cable during manufacture or installation, or breathed in at porous joints or leaky potheads during operation, is believed to be the principal cause of the oxidation exhibited by the radial hydrophil curves. There is some supporting evidence for this point of view. First, it is common experience that water can penetrate 50 or 100 ft along the filler spaces and between the conductor strands of *H*-type cable. Air should penetrate even farther than water; the layers of insulation near the sheath and near the conductor therefore could become oxidized, resulting in roughly U-shaped curves. It does not appear that these curves can be due to a slight a-c electrolysis of moisture in the insulation, because the shapes of the curves obtained on both *H*-type and belted cable are not consistent with such an explanation. Occasionally radial hydrophil curves were obtained in which oxidation had occurred at either the conductor or the sheath only, apparently showing that air which had penetrated along a single channel furnished the necessary oxygen. Again, it has been found that a new cable which yielded a flat radial hydrophil curve when delivered, yielded a roughly U-shaped hydrophil curve after one year's storage in spite of the fact that immediately after cutting of the original sample the cable end had been meticulously sealed; see Fig. 6. A similar finding was made on another sample which had been similarly sealed and stored for one year, Fig. 7. In this case no measurements of the types here under consideration were made upon the cable as received but there is reason to believe that the hydrophil curves were flat. The radial power factor curve of Fig. 7 tends to confirm the radial hydrophil curve and to indicate that some change has occurred in the cable. The most probable source of the deterioration appears to be oxidation due to inbreathed air.

A more exact correspondence between radial power factor and hydrophil is not always obtained because the power factor is measured on a long piece of tape whereas the hydrophils are often measured on a shorter piece. Since deterioration is not always uniform along the length of the tape, it is obvious that the power factor values may be more representative of the general deterioration than hydrophil values.

In interpreting the curves which have been presented, stress must not be placed upon the differences in the absolute value of hydrophil content which will be seen from the figures to vary from cable to cable within rather wide limits without a corresponding change in the power factor values. It cannot be expected that a constant ratio will obtain between power factor and hydrophil content, especially when different cable compounds are being compared as in the work just described. The important thing to watch for is similarity in character of the radial hydrophil and power factor curves.

In comparing the radial power factor and hydrophil curves, attention should be directed only to the correspondence of maximums and minimums, since the vertical scale of one or the other could be adjusted to produce an unfair similarity. The same end might also be accomplished by varying the temperature of the power factor measurement; the low portions of the curve would not greatly change position with temperature, whereas the high portions would be sensitive to temperature variation.

Effects of Exposure of Tape During Measuring.—The errors due to exposure of the paper tapes to the air in the interval between their removal from the cable and their measurement in the power factor cell have been studied. The effect of moisture and oxidation together was determined by hanging up

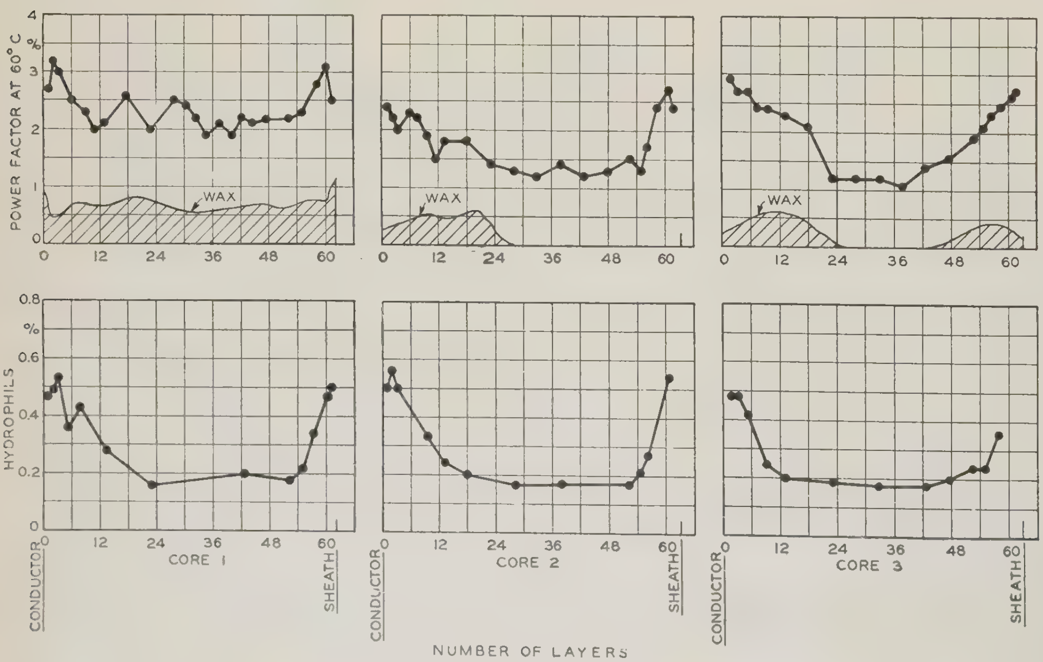


Fig. 5. Power factor, oxidation products, and wax for individual layers from conductor to sheath of 3 cores of a cable after 4 years in service

tapes in the laboratory atmosphere and measuring at intervals. The results on several tapes are given in Table I. The effect of oxidation alone was determined by placing selected tapes in a glass tube flushed out with carefully dried air. The results are given in Table II. The small change exhibited by sample 1 in Table II as compared with that of samples 2 and 3 may be explained on the basis that the latter were selected from a zone where intense ionization had taken place, resulting in the production of unsaturated hydrocarbons. The latter oxidize much more rapidly than the original oil. The effect of handling the tapes between the bare fingers cannot be detected by the power factor cell.

Table I—Effect of Exposure of Deteriorated Paper Tapes to Laboratory Atmosphere

(Average Relative Humidity = 35 Per Cent)

Total Elapsed Time of Exposure		Sample 1	Sample 2
Hr	Min		
0	0	2.6	2.8
0	5	2.6	2.8
0	50	3.2	3.5
27	10	10.2	10.8
48	40	10.6	11.8

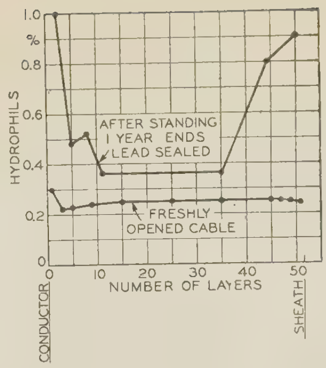
Table II—Effect of Exposure of Deteriorated Paper Tapes to Dry Air

Total Elapsed Time of Exposure		Sample 1	Sample 2	Sample 3
Hr	Min			
0	0	2.4	1.2	2.7
28	0	2.4	4.6	3.8
37	30	2.5	4.8	4.1

From these data it may be concluded that adsorption of moisture is the major cause of increase in power factor when oil impregnated paper tapes are exposed to laboratory air, although oxidation also plays a part. Neither of these effects produces a measurable change within a 5-min period, so that the short exposure in unwrapping tapes from cable has no influence on the power factor measurement.

The hydrophil and wax characteristics which have been plotted radially for these cables are not always sufficient to explain the variations in the radial power factor curve. For example, the radial power factor is sometimes found to turn upward near the sheath, whereas the hydrophil curve is flat, even when no ionization has been present. In such a case it is thought that the increase in power factor may be due to moisture adsorbed before the application of the lead sheath. It is regrettable that so far no method for moisture determination sensitive enough for a tape-by-tape investigation is available.

Occasionally other deteriorating agencies may become sufficiently pronounced as to obscure any relationship between radial power factor curves and radial hydrophil and wax curves. Besides infiltration of moisture, solution of copper in the impregnating oil near conductor and shielding tape, which has been found to take place to a small extent in cables, may in certain cases affect the radial power factor curves.



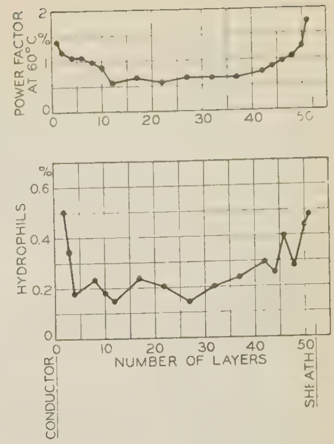


Fig. 6 (Left). Oxidation products of individual layers from conductor to sheath of a cable as received from factory and after one year's storage

Fig. 7 (Right). Power factor and oxidation products of individual layers from conductor to sheath of new cable after standing reeled for one year

An irregularity is frequently noted in the hydrophil curve within a few layers of conductor or sheath. This is thought to be due both to the dilution effect of the excess oil between the conductor strands, and to solution of traces of copper in the oil. The decrease in power factor of the second layer from the conductor is in some deteriorated cables marked. The effect is often found at both copper conductor and shielding tape in *H*-type cable, but only at the conductor in belted type.

An interesting observation is that most of the oxidation products are concentrated in the oil within the paper tape rather than in the excess interlayer oil on the outside of the tapes. This is shown by separate hydrophil determinations on oil wiped off the outside of the tape, and on oil dissolved by means of benzol from within the tape.

Conclusions

Application of the radial method to a number of used cables leads to the following conclusions:

1. Deterioration of cable insulation in a radial direction is nonuniform.
2. A major cause of deterioration of solid-type cables in service is oxidation. Oxidation also causes deterioration of cable during storage in the cable yard.
3. Leakage of air into and along the cable, either at time of installation or during operation, and air occluded in the cable at time of manufacture, are probably responsible for the oxidation of the insulation.
4. Ionization, as indicated by wax deposits, does not appear to cause sharp increases in dielectric loss.
5. The deterioration of 3-conductor cables is frequently markedly different on 1 core than on the other 2.

The new tools should prove of practical value in the study of a number of insulation problems. They

will be useful in determining the nature and source of the deterioration which goes on in cables in storage and in service, and how this deterioration progresses with years of service. They should also show the part that leaky joints and potheads play in causing deterioration and the remedial effect of oil reservoirs. They should throw new light on many abnormal types of deterioration. In addition the new tools should be helpful in checking and improving the manufacturing processes. In all cases where deterioration is experienced with thin laminated insulation as in cables, condensers, and transformers, application of the new tools should constitute a valuable diagnostic method.

Compensating Metering in Theory and Practice

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Outstanding economies can be effected by metering high voltage loads on the low voltage side of power transformers, a practical method of which is described in this article. A compensating meter is used in combination with a watthour meter, both connected to instrument transformers on the low voltage side; accuracy is equal to, and sometimes better than, metering on the high voltage side. Calculations illustrating the practical application of the method, and performance data for an actual installation are given.

MEASUREMENT of high voltage energy from the low voltage side of a power transformer bank presents several advantages from both an engineering and an economic point of view. In general, the higher the voltage, the greater is the differential in cost between high and low voltage metering, and the greater is the economy if low voltage metering of the requisite accuracy can be provided.

High voltage instrument transformer equipment, especially current transformers of suitable accuracy for metering, is particularly vulnerable with respect to damage by lightning and other disturbances. This applies mainly to suburban and rural territory, while in congested districts the space required for high voltage instrument transformers is frequently at a premium.

Engineers both in the United States and abroad have given considerable thought to various methods of providing low voltage metering for measurements as of the high voltage side. The methods in use are:

1. The application of compensating devices in the meter current and voltage circuits to correct for the ratio and phase-angle characteristics of the power transformers. Complete compensation by this method is relatively complicated, and in practice the initial calibration and the periodic checking of the compensating devices are usually beyond the scope of the average meterman.

2. Adjusting low voltage meters so that their registration includes approximate increments for transformer losses.[1] This method is used to some extent in Europe, but in the United States has been confined to statistical metering. A disadvantage of the method for billing purposes is that the meter does not record the true energy that passes through it.

3. In step-down transformers, current transformers on the high voltage side with potential from the low voltage side of the power transformers; or potential transformers on the high voltage side and current from the low voltage side. The former includes core losses but omits copper losses, while the latter includes copper losses but omits core losses. Both methods give less than the true high voltage registration.

4. Compensating metering, which has been developed to provide a practical commercial method of metering of accuracy equal to that of metering on the high voltage side.

Full text of a paper (No. 33-87) presented at the A.I.E.E. summer convention, Chicago, Ill., June 26–30, 1933.

Losses in power and distribution transformers commonly are divided into iron and copper losses; the general characteristics of these losses for a 7.5-kva transformer are shown in Fig. 1.

Iron losses consist of those due to magnetic hysteresis and those due to eddy currents, and are constant for constant voltage and frequency. With constant frequency, iron losses vary approximately as the square of the applied voltage; this has been verified by tests (see Fig. 2). Tests have been made also for the effect of temperature on iron losses, and this has been found negligible. Variations in frequency have an appreciable effect on iron losses; but in view of the stability of modern transmission and distribution systems, their effect is of minor importance. The tests have included also the effect of voltage variation on reactive voltamperes of the iron loss (see Fig. 2), and in different transformers this has been found to vary as $E^{3.5}$ to $E^{4.1}$, in general approaching closely to E^4 (where E is the applied voltage).

Age may have an effect on iron loss, but this applies only to transformers constructed prior to 1915. Different manufacturers adopted non-aging silicon steel cores at different times but in general between 1905 and 1910. The present iron losses of these older transformers are generally greater than that shown by the original factory tests.

Test results of copper losses indicate that both watts and reactive voltamperes vary as the square of the load current. Because of the temperature coefficient of copper, however, these losses increase approximately 20 per cent with an increase in temperature from 25 to 75 deg C (see Fig. 1).

Principle of Compensating Meter

Transformer losses may be measured by a meter the registration of which at all loads is in accordance with the total loss curves of Fig. 1; such a compensating meter consists of an I^2 element calibrated in accordance with the copper loss, and an E^2 element calibrated in accordance with the iron losses of the transformer. Both elements are combined on the same shaft, which drives a register of the proper ratio to record the losses in kilowatthours.

Figure 3 shows the general arrangement of a compensating meter that operates on the principle of the induction watthour meter. The lower element serves for the measurement of copper losses, and it is apparent that the currents in both the current and "voltage" coils are proportional to the load current; in the upper or iron-loss element both the voltage and "current" coils carry currents proportional to the applied voltage. The torques of the 2 elements therefore vary as I^2 and E^2, respectively, and their cumulative effect is recorded by the register.

In calibrating a meter of this type it is apparent that a definite current (for example, 5 amp) represents by design a certain speed of the disk, which in turn represents a definite copper loss in watts for a given transformer. The value in watt-seconds for one revolution then may be calculated, and the required register ratio to record in kilowatthours may be determined.[7] In practice the speed of the disk may be varied by adjusting the permanent magnets, and hence, the meter may be calibrated for use with standard register ratios (see sample calculations, Appendix *A*).

In adjusting the iron-loss element at a given voltage, the adjustable resistor is used. With no current in the copper-loss element, on the basis of the watt-second constant as determined for the copper-loss element, the upper element is adjusted for iron loss at the test voltage.

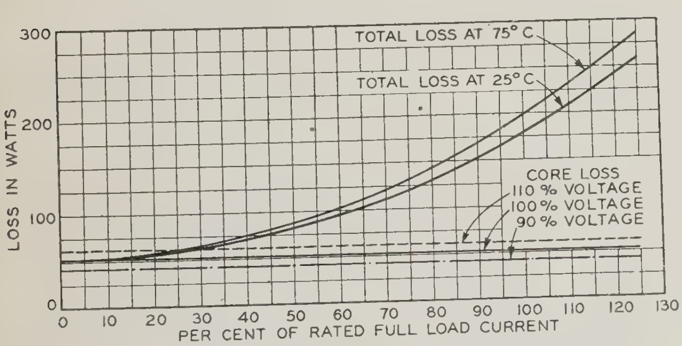
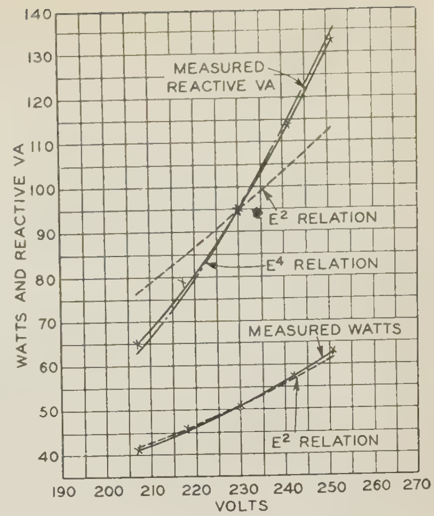


Fig. 1. Loss characteristics of a typical 7.5-kva distribution transformer

Core losses vary approximately as the square of the voltage; copper losses as the square of the current. Effects of temperature on core loss are negligible; effects on copper loss are shown by the curves

Fig. 2. Variation of iron losses in a 7.5-kva distribution transformer

Watt losses vary nearly as the square of the voltage. Reactive-voltampere losses vary approximately as the fourth power of the voltage, and their characteristics vary slightly in different transformers



Transformer losses on polyphase circuits may be measured by applying a number of single-phase compensating meters, or the several elements may be combined into a multi-element meter as in Fig. 4.

Accuracy Considerations

In considering the accuracy of the compensating meter, 2 conditions require consideration: (1) the effect of temperature variations of the transformer on copper loss measurement; and (2) the effect of transformer voltage regulation on iron-loss measurement. While it is possible to design compensating meters to correct for these inaccuracies, it can be shown that their effect in terms of load-plus-loss is entirely within the accuracy within which it is possible to maintain watthour meters on high voltage circuits. It should be noted that the relation of loss registration to total energy is dependent largely upon the load, and with full load on a transformer the total loss generally will be less than 2 per cent of the load. It follows that even a 10-per cent error in losses would result in only 0.2-per cent error in load-plus-loss. At no-load, when the losses represent the total high voltage load, the effect of voltage regulation is zero, and hence the iron loss measurement is accurate under this condition.

Temperature Variation and Voltage Regulation. The higher operating temperatures in transformers are associated with higher copper losses, and therefore it is advantageous to base the copper loss adjustment on a temperature at or near the full load operating temperature of the transformer. The 75-deg C copper loss has been used as the basis of adjustment for all calculations, tables, and tests.

The practical effect of both voltage and temperature variation has been calculated for a wide variety of conditions in Table I, which shows the percentage error in terms of load-plus-loss for a 7.5-kva transformer. In practice these errors will be less than those shown, since compensating metering generally would not be installed on transformers as small as 7.5 kva. Voltage regulation curves for the transformer considered are shown in Fig. 5, and Fig. 6 shows the accuracy performance graphically under the condition of maximum error.

High Voltage Metering Performance. The performance of high voltage metering is of interest as a basis of comparison. Figure 7 shows typical accuracy characteristics for 2 types of meters connected to modern instrument transformers. The curves are based upon perfect adjustment of the meters, which are adjusted to correct for instrument transformer errors at the 3 setting points. Commercial tolerance generally would be of the order of ±0.5 per cent from the values shown, and therefore the actual performance obtained in service would deviate to some extent from the curves. Some variations would result also from minor differences in characteristics between different meters and instrument transformers. It should be noted that the measurement of iron loss alone, which occurs on a high voltage installation at times of no load, is only with considerable error. The exciting current of modern transformers is of the order of about 2.0 per cent of the transformer rating, at power factors that may be as low as 10 to 20 per cent. A 10- to 20-per cent error in the measurement of iron losses alone on a high voltage installation is not unusual; and in some cases iron loss alone is not measured at all, since its value is less than the starting load of the meter (see Table II, Appendix *B*).

Table I—Effect of Voltage Regulation and Variation in Operating Temperature on the Accuracy of Load-Plus-Loss Measurement for a 7.5-Kva Distribution Transformer*

		Per Cent Error in Load-Plus-Loss Measurement				
		Per Cent Power Factor				
Temp. Deg C	Per Cent Full-Load Current	100	80 Lagging	60 Lagging	30 Lagging	60 Leading
25	0	0.00	0.00	0.00	0.00	0.00
	25	+0.05	+0.05	+0.07	+0.14	+0.13
	50	+0.13	+0.15	+0.20	+0.40	+0.26
	75	+0.20	+0.24	+0.32	+0.63	+0.38
	100	+0.28	+0.34	+0.45	+0.90	+0.51
50	0	0.00	0.00	0.00	0.00	0.00
	25	+0.02	+0.02	+0.02	+0.06	+0.08
	50	+0.07	+0.08	+0.10	+0.21	+0.16
	75	+0.12	+0.14	+0.19	+0.40	+0.25
	100	+0.17	+0.20	+0.26	+0.52	+0.32
75	0	0.00	0.00	0.00	0.00	0.00
	25	−0.03	−0.04	−0.06	−0.10	+0.01
	50	−0.03	−0.04	−0.06	−0.10	+0.01
	75	−0.03	−0.04	−0.06	−0.10	+0.01
	100	−0.03	−0.04	−0.06	−0.10	+0.01
85	0	0.00	0.00	0.00	0.00	0.00
	25	−0.05	−0.08	−0.10	−0.18	−0.04
	50	−0.08	−0.11	−0.14	−0.26	−0.08
	75	−0.11	−0.14	−0.19	−0.34	−0.12
	100	−0.13	−0.17	−0.23	−0.42	−0.15

* Copper-loss element adjusted on the basis of copper loss at 75° C, and core loss on the basis of no-load voltage.

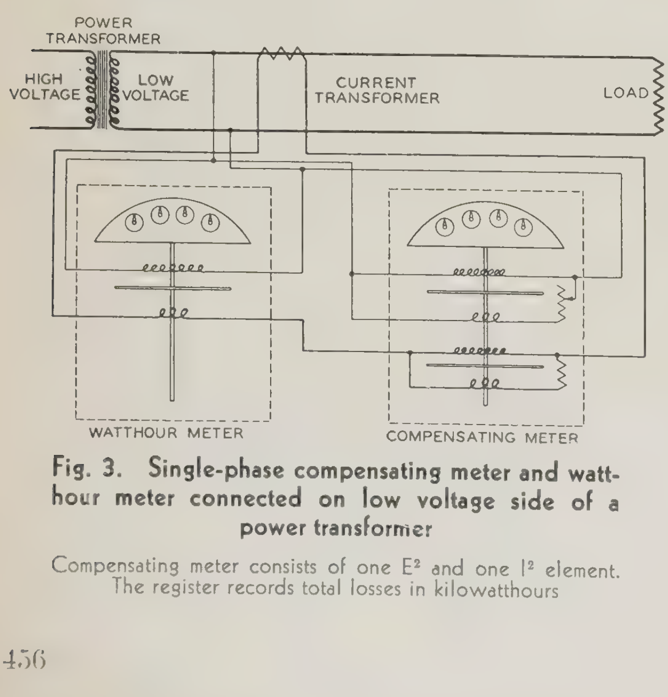


Fig. 3. Single-phase compensating meter and watthour meter connected on low voltage side of a power transformer

Compensating meter consists of one E^2 and one I^2 element. The register records total losses in kilowatthours

Practical Application

Consideration of the characteristics of high voltage customers' loads has made possible a practical simplification of compensating meters for such service. While theoretically, one compensating meter element is required for each transformer in a bank, the considerations discussed under "Accuracy Considerations" have made possible the development and use of a simplified form suitable for most commercial polyphase services. Such a meter consists of 2 I^2 elements and 1 E^2 element. A precaution with Δ-connected transformer banks is that the impedance and reactance characteristics of the three transformers must be alike so that there may be no circulating current.[4] This may be checked by calculation.[4] Any bank in which there is an appreciable circulating current, however, is objectionable also from the point of view of transformer operation and should be corrected. If the transformers be such that the circulating current is negligible, the 2 copper-loss elements can be calibrated for the total copper loss of the 3 transformers and the core-loss element for the total core loss of the 3 transformers. In a meter of this form, copper loss measurement is accurate for 2-phase and for 3-phase open-Δ transformer banks, and core loss measurement is exact when the voltages are balanced. For 3-phase Δ-connected transformer banks the meter would be accurate for balanced load and voltage conditions. In commercial practice exact balance is rare; but as indicated under "Accuracy Considerations," an error in loss measurement of even 10 per cent becomes negligible when considered in terms of combined load-plus-loss.

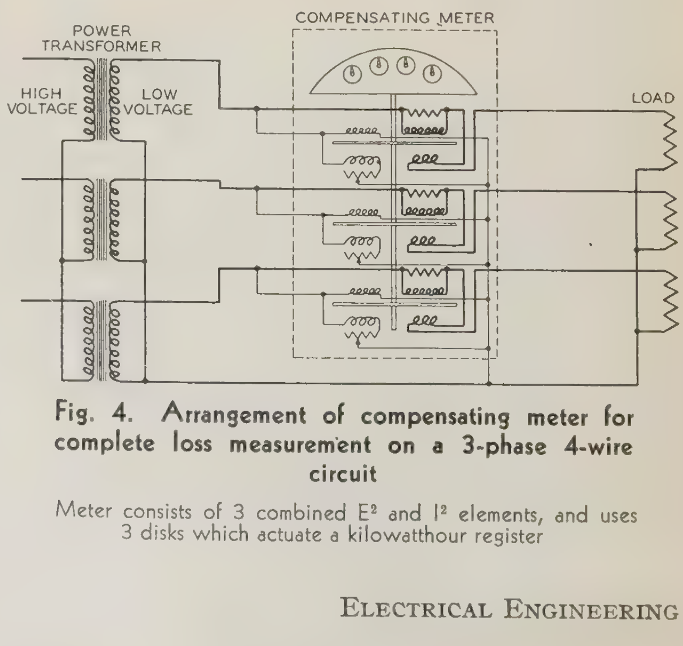


Fig. 4. Arrangement of compensating meter for complete loss measurement on a 3-phase 4-wire circuit

Meter consists of 3 combined E^2 and I^2 elements, and uses 3 disks which actuate a kilowatthour register

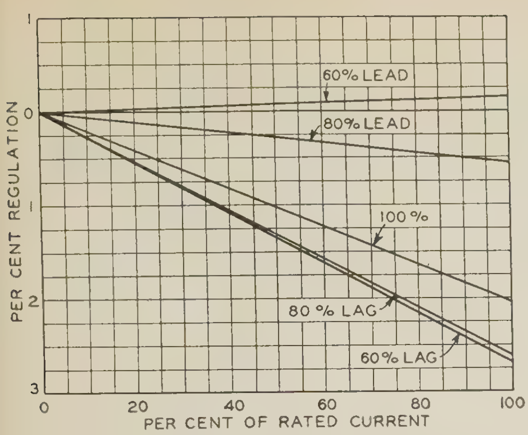
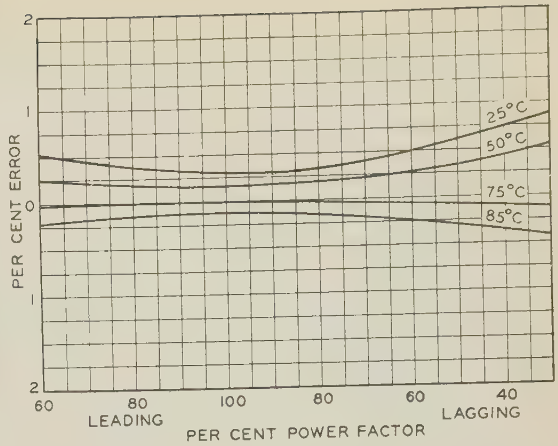


Fig. 5. (Left) Voltage regulation curves for a typical 7.5-kva distribution transformer

Fig. 6. (Right) Effect of voltage regulation and temperature on the accuracy of load-plus-loss metering

Curves show the maximum condition of error, which occurs with full load on the transformer; see Table I for accuracy at smaller loads



As an example of an hypothetical case of an extreme condition of unbalance, a bank of 3 100-kva transformers (losses in accordance with sample calculations, Appendix *A*) may be considered as carrying a single-phase load of 100 kva at unity power factor with no load on the other 2 phases. The condition of maximum error occurs when the load is connected so that the load current flows through both copper-loss elements. Under this condition the error in loss measurement approximates +21 per cent, but in terms of load-plus-loss less than +0.4 per cent.

Conditions such as these rarely if ever would occur in practice. The errors indicated may be eliminated by providing compensating metering for each transformer. It is apparent, however, that the magnitude of these errors would not warrant the installation of the more complicated metering arrangement. This example has been cited to indicate that such load unbalance as may be expected on polyphase services would not affect the accuracy of the combined load-plus-loss measurement beyond permissible limits of tolerance, even when a lighting load is connected to one phase of a 3-phase bank.

Measurement of Loss Demand

The maximum demand of the loss may be measured with a demand meter by providing contacts for its operation or by the addition of standard maximum demand devices. The maximum loss demand always will be coincident with the maximum load demand in kilovoltamperes, and if the load power factor be constant the loss maximum demand will be coincident with the maximum kilowatt demand. Customers' power factors, however, are not necessarily constant, and theoretically it would be possible for a customer to have a maximum kilowatt demand of 20 kw at unity power factor (20 kva) and a maximum kilovoltampere demand of 10 kw at 10 per cent power factor (100 kva). In practice, however, such conditions do not exist. Table IV in Appendix *B* shows the relation of kilowatt to kilovoltampere maximum demands of 30 typical customers' loads, together with the effect on accuracy of using the maximum loss demand instead of the simultaneous loss demand in determining the combined value for load-plus-loss. The maximum error noted was 0.14 per cent, which is entirely negligible in the commercial measurement of maximum demand. It follows that the loss increment of maximum demand may be measured by applying a watthour demand register to the compensating meter.

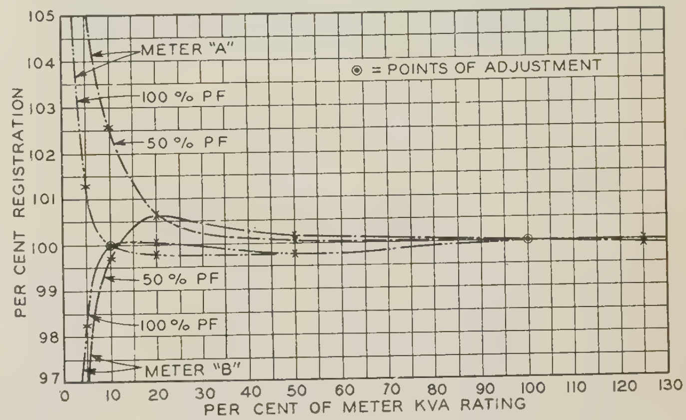


Fig. 7. Characteristics of 2 types of watthour meters with instrument transformers for high voltage installations

Curves are based upon perfect adjustment of the meters at the 3 setting points at which the meter has been compensated to correct for instrument transformer errors. Note performance at extremely light loads at low power-factor, which condition exists when exciting current only is measured on a high voltage installation

Measurement of Reactive Kilovoltampere-Hours

Reactive kilovoltampere-hours of transformer losses may be measured with a compensating meter by calibrating it in accordance with the reactive kilovoltamperes of the core and copper losses. It is evident from Fig. 2 that the core-loss element should be adjusted at about the average operating voltage, since reactive voltamperes vary more nearly in accordance with the fourth power of the voltage rather than with the square as measured by the compensating meter. The error introduced into the determination of power factor is smaller than that introduced into the reactive kilovoltampere-hour measurement. For low power factors the reactive kilovoltampere-hours of the transformer losses will be a relatively small percentage of the total, while near unity power factor a much larger change in reactive kilovoltampere-hours is required for a given change in power factor. The errors introduced into

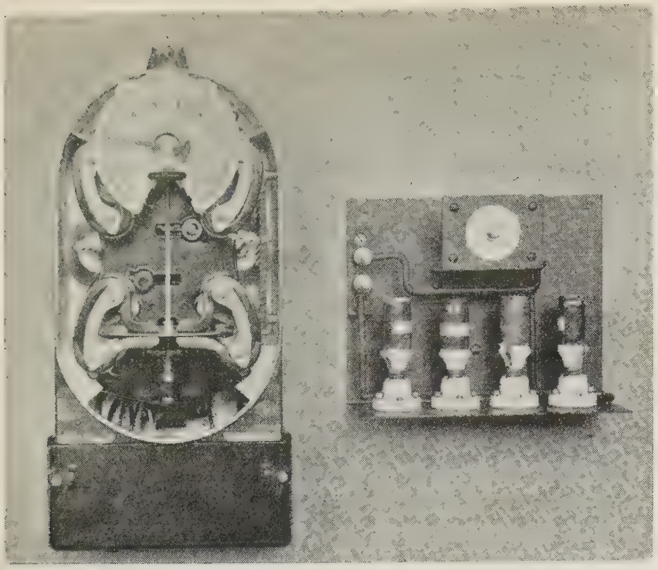


Fig. 8. A single-phase compensating meter showing separate resistor assembly for core loss element

Meter consists of one E^2 element and one I^2 element. Watthour demand register gives losses in kilowatthours and maximum loss demand in kilowatts. Resistor assembly serves for calibrating the core loss element

the power factor determination would be within the limits of commercial tolerance except for conditions where the installed transformer capacity is much greater than the maximum demand of the load. Table V in Appendix *B* has been calculated for an assumed load factor of 25 per cent, and covers operation at several power factors for various conditions of maximum demand as related to transformer rating. It should be noted that the errors shown are for a 10-per cent difference between the actual average voltage and the voltage for which the meter was calibrated during the entire reading period. It is apparent that when the meter is calibrated at or near the true average voltage, the errors will tend to cancel.

Calibration and Testing

The method of calibration of the compensating meter with an ammeter and a voltmeter is self-evident from the general description of the method and from the sample calculation in Appendix *A*. Service tests may be simplified by using a rotating standard operating on the principle of the single-phase compensating meter, in which case compensating meters may be tested in service by one man.

Economics

The desirability of using a compensating meter in preference to metering on the high voltage side will depend largely upon the savings to be effected, with due consideration to all features. A compensating meter installed would cost from \$150 to \$200 in addition to the cost of standard metering at the low voltage. Load-plus-loss metering equipment on the low voltage side usually may be installed indoors in buildings already available; for high voltage installations, the greater cost of instrument transformer equipment, increased construction costs, the possible necessity for constructing special meter houses, or the erection of additional poles for mounting outdoor instrument transformer equipment must be considered. Savings in space and the economic value of greater safety and continuity of service, as well as a possible greater accuracy of registration, all have a tangible value. Since practices and service conditions vary in different localities, the possible economies that result from the use of compensating metering may be evaluated only by considering the particular conditions which apply.

Conclusion

It is apparent that the compensating meter makes practical the measurement of high voltage energy from the low voltage side of power transformer banks, with an accuracy equal to that of high voltage metering. Under some conditions improved accuracy results; and for the measurement of energy as of a remote point on the supply lines, the method is particularly advantageous.

The cost of adding a polyphase compensating meter to a standard low voltage installation is of the order of \$150 to \$200, and in comparison the greater cost of instrument transformer equipment alone frequently will be much greater for the higher voltage installations. Additional savings usually will result also from the lower construction costs for low voltage as compared with high voltage metering.

In practice, there are a few cases for which the compensating meter may not prove as economical as metering on the high voltage side. Examples are: (1) customers who are supplied by a relatively large number of transformer banks, all connected to one high voltage service; and (2) customers who operate part of their equipment at the service voltage.

For the usual types of high voltage installations, either customers' billing or statistical, the application of the compensating meter will frequently result in

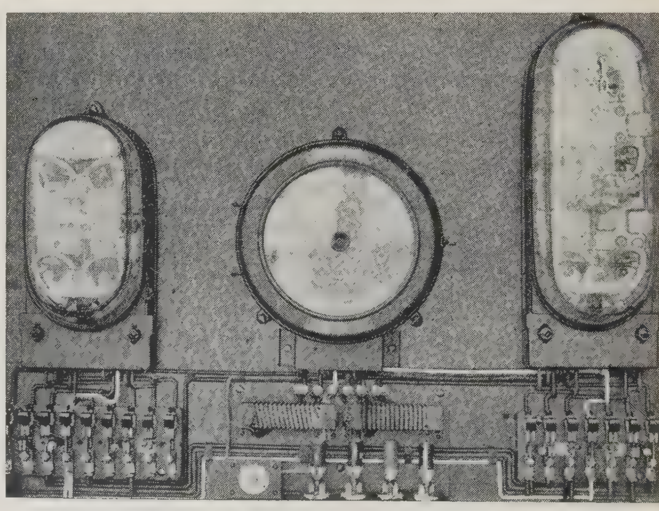


Fig. 9. Typical polyphase compensating meter panel

Includes polyphase load meter (left) simplified form of polyphase compensating meter (right) and graphic demand meter (center) with test switches and resistor assembly in lower section

important economies. The method is of particular advantage:

1. When the cost of load-plus-loss metering is less than that of metering on the high voltage side.

2. When the limited space available makes the installation of high voltage metering more difficult, and hence more expensive.

3. When the load conditions are such that the power transformers may be energized for considerable periods without carrying load.

4. For exposed locations on the system where ordinary high voltage instrument transformer equipment may be expected to give trouble because of lightning or other disturbances.

5. When it is desired to obtain registration as of the high voltage side to a point remote from the metering location.

6. When a customer with a rate for low voltage service and with metering already installed, is changed to a high voltage service rate.

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Appendix A—Sample Calculations

The application of a compensating meter to a specific installation will serve to illustrate the method of determining the initial calibration both for energy and reactive kilovoltampere-hours, and for the determination of power factor as of the high voltage side, on the basis of a test on the low voltage side.

Conditions Assumed. A bank of 3 100-kva Δ-Δ transformers, 13,800/230 volts, supplies the total load of a high voltage customer. It is desired to measure both energy and demand as of the 13,800-volt side, using a 230-volt 800-amp meter and a compensating meter. The secondary metering equipment is connected to the power transformer secondaries by 3 1,500,000-cir mil cables, each 20 ft long.

Calibration of Compensating Watthour Demand Meter. The manufacturers of the transformers supplied the following data:

Transf. No.	Core Loss at Rated Voltage	Copper Loss at Full Load	Per Cent *IZ* Drop	Per Cent Exciting Current
(a)	380	1,175	4.1	3.0
(b)	360	1,165	4.05	2.8
(c)	372	1,171	4.1	2.9

Total core loss at 13,800 volts = 380 + 360 + 372 = 1,112 watts . . . . . (1)

Total copper loss at full load on power transformers (753.1 amp secondary) = 1,175 + 1,165 + 1,171 = 3,511 watts . . . . . (2)

Using 800-amp current transformers, copper loss at full load on current transformers (5-amp secondary) =

$$\frac{800^2}{753.1^2} \times 3{,}511 = 3{,}962 \text{ watts} \quad \ldots\ldots (3)$$

Copper loss in cables (I^2R) =

$$\frac{800^2 \times 0.0072 \text{ ohms} \times 20 \times 3}{1{,}000} = 276 \text{ watts} \quad \ldots\ldots (4)$$

Total copper loss at 800 amp = 3,962 + 276 = 4,238 watts . . . . (5)

The compensating meter as supplied makes one revolution in 3.6 sec with 5 amp in the current circuit (both I^2 elements). To calibrate the compensating meter to read in kilowatthours, the normal watt-second constant would be

K_s = 4,238 × 3.6 = 15,256.8 watt-seconds per revolution of the disk . . . . . (6)

To use a standard register, it is necessary to have a standard watt-second constant. By referring to the manufacturers' table of standard registers and constants, the watt-second constants closest to that desired are 17,280 and 12,960. Either of these watt-second constants may be used, and the choice may properly be made by selecting the one for which the demand scale of the watthour demand register provides sufficient overload capacity in relation to the full load losses.

Total losses at 800 amp (Items 1 and 5) =
(380 + 360 + 372) + (3,962 + 276) = 5,350 watts . . . . (7)

Assume the use of a standard watthour demand register with a scale of 10.2 kw, a gear ratio of 2,777-7/9, operating with a watt-second constant of 12,960. (Register constant = 1.) The copper loss elements then must be recalibrated for a speed faster than 3.6 sec per revolution.

Required seconds per revolution =

$$\frac{K_s}{\text{Total Copper Loss}} = \frac{12{,}960}{4{,}238} = 3.058 \text{ sec} \quad \ldots\ldots (8)$$

The core loss element then must be calibrated so that at 230 volts its torque will be equivalent to 1,112 watts.

Seconds per revolution at 230 volts =

$$\frac{K_s}{\text{Total Core Loss}} = \frac{12{,}960}{1{,}112} = 11.655 \text{ sec} \quad \ldots\ldots (9)$$

For tests in service at other voltages, 225 volts for example:

$$\text{seconds per revolution} = \frac{230^2}{225^2} \times 11.655 = 12.178 \text{ sec} \quad \ldots\ldots (10)$$

Calibration for Compensating Reactive Kilovoltampere-Hour Meter. If it be necessary to measure average monthly power factor, a standard reactive voltampere-hour meter may be used on the low voltage side, and a compensating meter added for reactive kilovoltampere-hours of the power transformer bank.

The procedure is the same as for the watthour meter, except that the calibration of the elements is based on the reactive instead of the energy components of the losses. The required reactive voltampere values are calculated from the data of the transformers. The remaining calculations are the same as for the energy loss meter, substituting reactive voltampere values for watts. The constants of the reactive meter usually will be different from those of the watthour meter for the same transformer bank.

For the installation under consideration, the following results are obtained from these calculations:

Total reactive voltamperes of core loss at 230 volts	= 8,629	(11)
Total reactive voltamperes of load loss at 800 amp	= 23,613	
Watt-second constant (K_s)	= 86,400	
Seconds per revolution for copper-loss element at 5 amp secondary (800 primary)	= 3.659	
Seconds per revolution for iron-loss element at 230 volts	= 10.127	
Gear ratio (R_g)	= 4,166-2/3	
Register constant (K_r)	= 10	

Reactive compensating meters should be calibrated at approximately the average operating voltage. (See Fig. 2 for characteristics of reactive voltamperes of core loss.)

Calculation for Power Factor Obtained by Test. If power factor be obtained by test (as for example, with indicating instruments) tests made on the low voltage side may serve as a basis for calculating power factor as of the high voltage side. For the installation under consideration, it is assumed that a power factor test on the low voltage side shows a load of 200 kw at 80 per cent power factor at 225 volts.

With this method the values determined for energy and reactive voltamperes of both core and load losses, in accordance with Items 1, 5, and 11, are supplied to the power factor tester.

The service calculations are as follows:

$$\text{Line current} = \frac{200{,}000}{0.80 \times 225 \times \sqrt{3}} = 627.6 \text{ amp} \quad \ldots\ldots (12)$$

$$\text{Watts copper loss} = \frac{627.6^2 \times 4,238}{800^2} = 2,608 \ldots\ldots\ldots\ldots\ldots (13)$$

$$\text{Watts iron loss} = \frac{225^2 \times 1,112}{230^2} = 1,064 \ldots\ldots\ldots\ldots\ldots (14)$$

Reactive voltamperes of load loss

$$= \frac{627.6^2 \times 23,613}{800^2} = 14,531 \ldots\ldots\ldots\ldots (15)$$

Reactive voltamperes of core loss

$$= \frac{225^4 \times 8,629}{230^4} = 7,904 \ldots\ldots\ldots\ldots\ldots (16)$$

Coordinating these values with the test results:

Load	Kw	Reactive Kva	Kva	Per Cent Power Factor
Low Voltage	200.00	150.00	250.00	80.0
Iron Loss	1.06	7.90		
Copper Loss	2.61	14.53		
High Voltage	203.67	172.43	266.9	76.3

Appendix B—Performance Under Various Conditions

Comparative Results for a Service Installation. This test was made in an office building supplied from 2 2,300-volt 2-phase 3-wire services, each connected to a bank of 2 250-kva 2,300:115/230-volt transformers. Either bank may carry the lighting or the power load, and in case of emergency both loads may be supplied from a single bank. Results of these tests are given in Table II.

Table V—Per Cent Error in Reactive Kilovoltampere-Hour Measurement and Its Effect on Power Factor for Differences in Applied Voltage From Calibrated Voltage for the Entire Reading Period

Based on: assumed load factor of 25 per cent; 3 100-kva transformers in accordance with sample calculation Appendix *A*

Maximum Kva Demand in % of Transf. Rating	Load Power Factor	Per Cent Difference in Reactive Kva-Hr			Difference in % Power Factor		
		Actual Avg. Voltage in % of Calibration Voltage					
		90	100	110	90	100	110
100	100	+11.9	0	−12.9	−0.29	0	+0.55
	86.6	+ 2.8	0	− 3.9	−0.81	0	+1.24
	70.7	+ 2.0	0	− 2.9	−0.76	0	+1.15
	50	+ 1.5	0	− 2.3	−0.50	0	+0.79
75	100	+15.4	0	−14.6	−0.40	0	+0.82
	86.6	+ 3.7	0	− 5.0	−1.08	0	+1.60
	70.7	+ 2.7	0	− 3.8	−1.02	0	+1.49
	50	+ 2.1	0	− 3.1	−0.72	0	+1.06
50	100	+19.9	0	−16.0	−0.70	0	+1.56
	86.6	+ 5.4	0	− 6.7	−1.61	0	+2.35
	70.7	+ 4 0	0	− 5.0	−1.52	0	+2.10
	50	+ 3.2	0	− 4.4	−1.09	0	+1.52
25	100	+24.0	0	−17.0	−2.08	0	+4.09
	86.6	+ 8.9	0	− 9.8	−2.91	0	+3.89
	70.7	+ 7.3	0	− 8.3	−2.71	0	+3.25
	50	+ 6.1	0	− 7.3	−2.08	0	+2.25

It should be noted that the table shows extreme conditions of error since it assumes differences between calibration and actual average voltage of 10 per cent *for the entire period of the reading.* When a true average voltage is used for the calibration test of the reactive kilovoltampere-hour meter, the errors will tend to cancel.

Table II—Comparison of Measured Input, Output, and Loss Kilowatthours on 2/250-Kva 2300:115/230-Volt Transformers

Elapsed Time (Days)	Interim Kilowatthours: Input Billing Meter (Polyphase)	Input Test Meters (Single-Phase)	Output Meters	Loss: A Phase	Loss: C Phase	Output-Plus-Loss	Per Cent Differences Between Reading Dates: From Input Billing Meter	From Input Test Meters
	Installed—Connected to power load (Approximate power factor = 75%)							
10	10,060	10,110	9,533	297.16	286.63	10,116.79	+0.56	+0.07
10	Meters tested							
21	8,330	8,360	7,770	294.76	289.72	8,354.48	+0.29	−0.06
30	7,100	7,120	6,580	261.03	254.76	7,095.79	−0.06	−0.34
40	6,580	6,570	5,987	292.71	289.13	6,568.84	−0.17	−0.02
50	7,000	7,040	6,440	294.54	288.51	7,023.05	+0.33	−0.24
Total power	39,070	39,200	36,310	1,440.2	1,408.75	39,158.95	+0.23	−0.10
	Meters tested Connected to lighting load (A-phase only) C-phase loss meter removed for tests in laboratory (see Table III)							
4		6,780	6,617	141.39		6,758.39		−0.32
4	Service oil switch opened for construction work							
15	Service oil switch closed—no load							
21		0*	0	178.97		178.97		+100.0*
21	Secondary load switch closed							
28		9,020	8,815	227.48		9,042.48		+0.25
35		10,600	10,372	239.46		10,611.46		+0.11
42		11,950	11,638	251.75		11,889.75		−0.50
49		9,910	9,634	232.45		9,866.45		−0.44
56		8,570	8,348	218.56		8,566.56		−0.04
63		11,150	10,882	245.93		11,127.93		−0.20
70		10,400	10,162	235.33		10,398.33		−0.02
77		3,460	3,373	72.79		3,445.79		−0.40
Total A-phase light		81,840	79,841	2,044.11		81,886.11		+0.06
Combined light and power	121,040	116,151		3,484.31	1,408.75	121,044.06		+0.003

* Input test meter did not register since core loss is less than the starting load of the meter (1,104 watts = 0.48 per cent of meter rating).
(+) signs indicate that output-plus-loss is greater than input registration
(−) signs indicate that output-plus-loss is less than input registration.

Comparative Results for a Test Installation. Two 7.5-kva 2300/230-volt distribution transformers were connected to transform from 230 volts to 2,300 and back to 230. Identical meters were connected to the input and output sides, and a compensating meter, adjusted for the losses of the transformers, was connected to the output side. The tests included a wide variety of load and power-factor conditions over a relatively short period of time; the results are given in Table III.

Table III—Comparison of Measured Input, Output, and Loss Kilowatthours for Tests on 2 7.5-Kva Transformers Under Various Load Conditions

(230/2,300–2,300/230-volt connection, single-phase load)

Per Cent Load on Power Transf.	Per Cent Load on Input Meter	Per Cent Power Factor (Input)	Per Cent Load Factor (Output)		Duration of Test (Hours)	Measured Output Kwhr	Measured Loss Kwhr	Measured Output-Plus-Loss Kwhr	Measured Input Kwhr	Per Cent Difference Between Input Kwhr and Output-Plus-Loss Kwhr	Possible Accuracy of Reading Registers (%)
0	1.0	35.0			187	0	21.038	21.038	20.975	+0.31	±0.7
0 100	1.0 66.0	35.0 99.1	8.33	22 2	24	14.527	3.208	17.735	17.625	+0.625	±0.6
0 100	1.0 66.0	35.0 99.1	33.3	16 8	24	59.587	5.005	64.592	64.635	−0.068	±0.15
0 100	1.0 66.0	35.0 99.1	50.0	16 16	32	119.122	8.372	127.494	127.57	−0.056	±0.065
100	66.0	99.1	100		16	119.071	6.735	125.806	125.87	−0.052	±0.066
25	17.3	98.6	100		16	53.701	2.137	55.838	55.95	−0.2	±0.183
15.9	11.4	25.5	100		17	18.454	3.968	22.422	22.375	+0.21	±0.49
43.8	29.6	79.0	100		16	50.301	3.042	53.343	53.450	−0.2	±0.19
71.2	47.5	89.0	100		15	75.023	4.138	79.161	79.35	−0.24	±0.13
58.5	39.2	99.0	100		24	98.052	4.762	102.814	102.75	+0.062	±0.10
51.7	34.8	85.0	100		15.5	55.100	2.998	58.098	58.25	−0.26	±0.18
8.9	6.7	25.0	100		17	10.129	2.510	12.639	12.55	+0.71	±0.90
7.3	5.7	24.5	100		64	33.405	9.023	42.428	42.275	+0.36	±0.30
21.2	15.0	46.8	100		21	43.592	3.210	46.802	46.80	+0.004	±0.22
Combined					314	750.064	80.146	830.210	830.425	−0.03	±0.006

(+) indicates that output-plus-loss is greater than input registration.
(−) indicates that output-plus-loss is less than input registration.

Table IV—Load Characteristics of 30 Typical Customers' Loads Showing Accuracy of a Watthour Demand Register for Measuring the Loss Increment of the Maximum Kilowatt Demand

Customer Number	Business Class	Measured Maximum Kw Demand	Measured Kva at Time of Maximum Kw Demand	Per Cent Power Factor at Time of Maximum Kw Demand	Measured Maximum Kva Demand	Per Cent Error in Indicated Loss Demand**	Per Cent Error in Indicated Load-Plus-Loss Demand
1	Shipbuilding*	1,875.0	2,180.0	85.9	2,180.0	0	0
2	Pressed steel specialties*	1,720.0	2,450.0	70.2	2,450.0	0	0
3	Chemical manufacturer*	1,500.0	1,705.0	87.9	1,725.0	+1.72	+0.048
4	Tire manufacturer*	1,368.0	1,547.0	88.3	1,547.0	0	0
5	Wool products*	1,300.0	1,424.0	91.2	1,424.0	0	0
6	Steel construction*	1,200.0	1,434.0	83.6	1,434.0	0	0
7	Textile mill	1,150.0	1,490.0	77.2	1,530.0	+3.90	+0.126
8	Sand and gravel*	1,040.0	1,145.0	90.8	1,145.0	0	0
9	Gear works*	800.0	895.9	89.3	895.9	0	0
10	Paper manufacturer*	672.0	736.0	91.2	736.0	0	0
11	Brick manufacturer*	552.0	552.6	99.9	552.6	0	0
12	Steel foundry*	515.0	566.0	91.0	566.0	0	0
13	Quarry	508.0	592.1	85.9	592.1	0	0
14	Lime quarry*	360.0	390.0	92.3	390.0	0	0
15	Steel tubing manufacturer*	163.5	182.5	89.5	182.5	0	0
16	Hosiery mill	160.0	181.6	88.1	182.2	+0.53	+0.015
17	Building material	147.3	226.0	65.2	226.0	0	0
18	Ice plant*	130.4	142.5	91.5	143.2	+0.75	+0.020
19	Textile mill	112.0	162.0	69.1	167.0	+3.99	+0.144
20	Sand and gravel	109.0	135.2	80.6	136.1	+0.97	+0.030
21	Conduit manufacturer	96.0	110.5	86.8	110.5	0	0
22	Hosiery mill*	79.6	92.3	86.2	92.3	0	0
23	Car repair shop*	64.8	68.7	94.5	68.7	0	0
24	Aircraft plant	63.6	89.6	71.0	89.6	0	0
25	Dairy	59.3	65.1	91.2	65.1	0	0
26	Steel construction*	57.6	64.4	89.4	64.4	0	0
27	Office building	54.8	75.0	73.2	75.0	0	0
28	Laundry	47.0	58.8	79.9	58.8	0	0
29	Signal service	43.2	52.3	82.5	53.3	+2.78	+0.083
30	Waste manufacturer	31.2	37.2	83.8	37.2	0	0

* These customers have power-factor corrective equipment.
** Loss demand in kw is considered to be 2.5 per cent of measured maximum kva demand. At the time of maximum kva demand, losses are taken to consist of 25 per cent core loss and 75 per cent copper loss.
(+) indicates that the loss maximum demand plus load maximum demand is greater than the load maximum demand plus the coincident loss demand.

Improvements in Mercury Arc Rectifiers

Since the sectional mercury arc rectifier was introduced a few years ago, many improvements have been made in the design of the rectifier unit as regards both performance and convenience of operation. These improvements have been incorporated in the design of the 3,000-kw 625-volt rectifiers being supplied for the New York City Independent Subway System. Performance of these new units and factors determining design features are discussed in this article.

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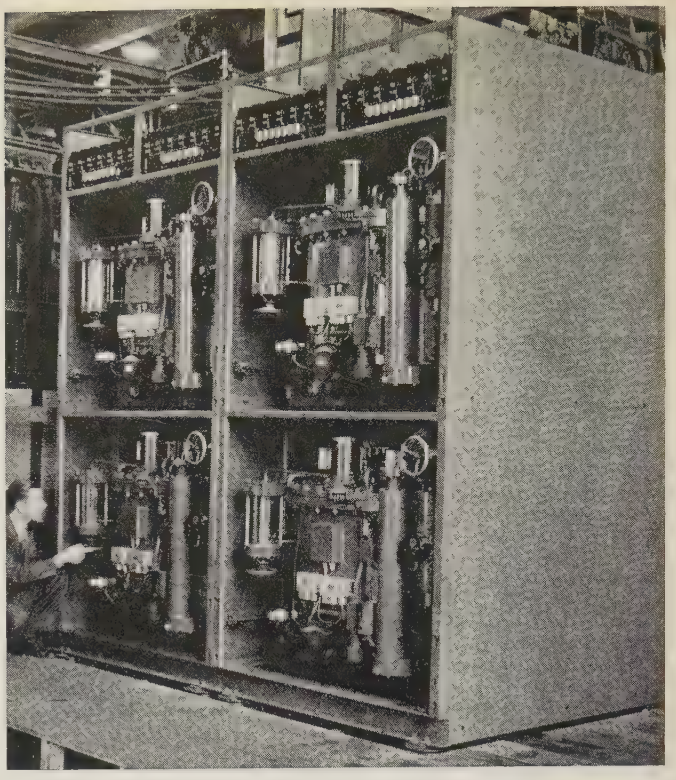

Fig. 1. 3,000-kw 625-volt 4-section mercury arc rectifier with truck type sections which can be taken out of service in a few seconds

THE PRINCIPLE of building large capacity rectifiers in sectional form was discussed in A. L. Atherton's paper ("High Capacity Rectifier Efficiency Improved by Sectionalizing," A.I.E.E. Trans., v. 51, 1932, p. 511–15) presented at the 1932 A.I.E.E. winter convention. Obviously, the successful achievement of a sectional rectifier, without its becoming prohibitively large, involved the development of a rectifier section greatly reduced in size from the familiar conventional rectifier of 500 to 1,000 kw capacity. Because of the characteristics of the device, this reduction in size of section inevitably resulted in a corresponding reduction in arc drop with a further enhancing of the advantage of the sectional arrangement. The design was based upon a 1,250-amp section, which is approximately the rating above which difficulties due to size begin. Mr. Atherton's paper briefly describes the first design of sectional rectifier. Since that time, considerable improvement has been made both in performance and convenience of operation. This paper describes the 3,000-kw 625-volt unit being installed on the Fulton Street line of the Independent Subway System of the City of New York; this unit is typical for any capacity above 750 kw at 600 volts. The paper also briefly describes smaller rectifiers for capacities below 750 kw.

During recent years great advances have been made in the knowledge of the fundamentals of the electric arc. This information facilitated the improvements made in the sectional mercury arc rectifier. (See "Backfire in Mercury Arc Rectifiers," by J. Slepian and L. R. Ludwig, A.I.E.E. Trans., v. 51, 1932, p. 92–104; "Mercury Arc Rectifier Research," by A. W. Hull and H. D. Brown, A.I.E.E. Trans., v. 50, 1931, p. 744–56; and "A New Method for Initiating the Cathode of an Arc," by J. Slepian and L. R. Ludwig, A.I.E.E., Trans., v. 52, 1933.) There are certain advantages in the arrangement of parts in the conventional type of metal tank rectifier. In the past, as the result of available experience, it was believed that a rather definite relationship existed between the cooling surface area and volume of a rectifier, and the maximum current carrying capacity. The empirical relationship adopted required a tank so large that its size was objectionable. It was pointed out by Dr. J. Slepian of the Westinghouse Company, East Pittsburgh, Pa., that no fundamental relationship of this sort exists. Doctor Slepian further suggested that since all vapor that comes into contact with a cooled surface condenses (thus the temperature of this surface determines the pressure of the vapor in the regions adjoining) in order to maintain the desired vapor density in the arc conducting regions it is necessary only to clear the way for the vapor to reach the condensing surfaces. If these surfaces be maintained at the desired temperature there is no limitation, that is approached in mercury arc rectifier practice, to the watts per unit area that can be dissipated. Therefore, in designing the improved sectional rectifier the basis used was a conventional rectifier with which a great deal of successful experience was available; but no attention was given to area of cooling surfaces, and the only considerations were that ample passages be provided

Full text of a paper (No. 33-83) presented at the A.I.E.E. summer convention, Chicago, Ill., June 26–30, 1933.

for the smooth flow of vapor from the source at the cathode to the condensing surfaces, so as to prevent undesirable rises in pressures. Also, the parts were so arranged that the vapor flow would sweep to the vacuum pumping connection such permanent gases as gather, and prevent any accumulation that would keep the vapor from reaching the cooling surfaces or from entering the arc path with objectionable results. Thus, since the amount of vapor coming from the cathode is proportional to the current and since it is essential that the correct vapor density be maintained, the current carrying limit is determined by the provisions for disposition of the mercury vapor, in addition, of course, to the thermal limitations of the current conducting parts. The voltage limitation of a rectifier is one of arc back which determines the amount of deionizing required in the arc path. The influence of this on size is small compared to that of provisions determined by current.

It is questionable if at the present time a temperature can be specified at which rectifiers in general operate with lowest arc drop (See "Recent Developments in High Current Mercury Arc Rectifiers," by E. H. Reid and C. C. Herskind, A.I.E.E. Trans., v. 52, 1933). Of prime importance is the ability to rectify without arcing back. Up to a certain point, raising the temperature lowers the arc drop; but also, except for low temperatures at which surges occur, it lowers the ability to withstand arc back. To counteract the tendency to arc back, in the present forms of rectifiers deionizing surfaces are interposed in the arc path; these raise the arc drop. Therefore, both temperature and deionizing devices must be considered and the optimum balance chosen. For a given arrangement of parts, the higher the temperature the greater will be the stability of the arc and the freedom from voltage surges. Of course a high water discharge temperature conserves the cooling water required, but usually the importance of this is secondary to that of rectifier efficiency.

Figure 3 shows a cross section of the resulting design, and indicates not only the compact arrangement of parts but also the wide, smooth paths for the vapor flow as discussed. The rectifier tank is equipped with a small dome from which the permanent gases are exhausted. Such gases as accumulate gather in this dome and, therefore, do not go into the region around the anode upon fluctuations in load with consequent fluctuations in vapor flow.

In addition to the large size of former rectifiers due to condensing surface constants, the usual form of anode shield and the provision for cooling the anode terminal with water, which frequently is employed, imposed a height requirement that was prohibitive. To reduce the anode structure length, additional grid length was substituted for the usual extra shield length with a net saving of several inches. Because of the narrower passages of the grid, each unit of grid length is equivalent to a much greater length of shield. The substitution of a small solid anode radiator for the necessarily large water filled radiator is the relatively simple matter of designing the parts so that the desired temperature gradient is obtained with a solid anode stem. This, of course, requires an arrangement of parts such that no part of the effective insulation operates at a temperature at which the insulating value of the material is reduced.

The anode of the sectional rectifier is shown in Fig. 4. Graphite is used as the anode head because it is not seriously damaged by arc back. Quartz is used for the grid because it is an insulating material with a high melting point and satisfactory mechanical strength. Making the grid of insulating material prevents the formation of a cathode spot on the grid with the resulting damage when passing heavy currents. Quartz is used also as anode insulation in critical locations, because it maintains its insulating qualities at relatively high temperatures and the tendency for breakdown to occur at the junction between quartz and a conductor is less than with most insulating materials. Shields and baffles are so arranged as to keep the spaces adjacent to the insulation deionized, thus keeping the insulation clean by preventing sputtering, and reducing the

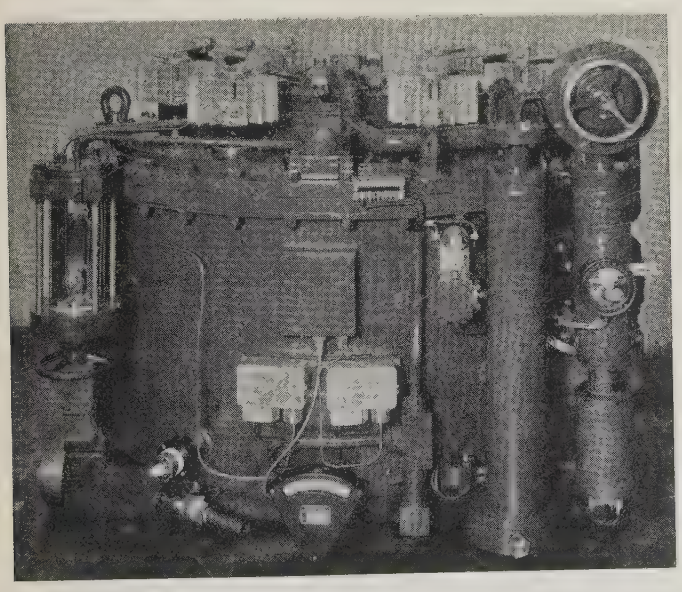

Fig. 2. One section of the rectifier shown in Fig. 1

These can be arranged in multiple for any capacity desired with no loss of efficiency, and the requirement for spare capacity reduced with increased size. Section shown is assembled with complete independent set of auxiliaries and contacts for truck type mounting

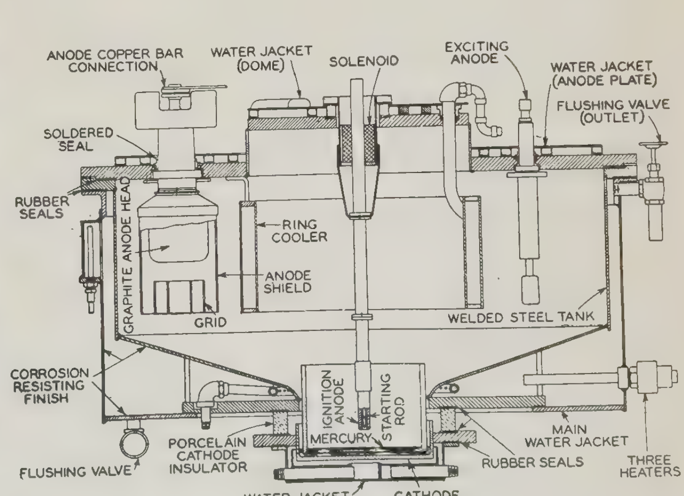

Fig. 3. Cross sectional view of the 1,250-amp rectifier section shown in Fig. 2

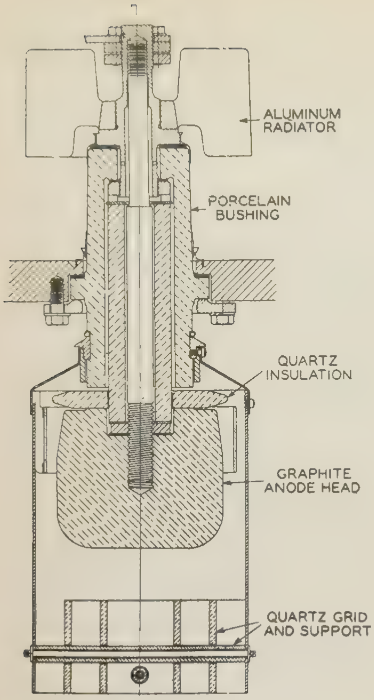

Fig. 4. Cross sectional view of rectifier anode

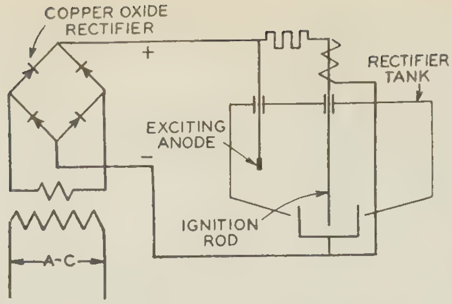

Fig. 5. Schematic diagram of ignition and excitation system

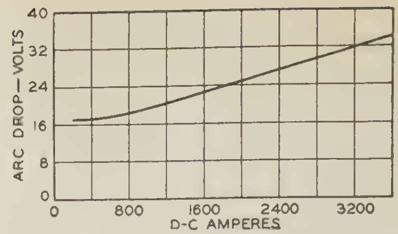

Fig. 6. Arc drop curve of sectional rectifier

tendency of the formation of a cathode spot with resulting arc back, at the junction between insulation and conductor.

The cathode is equipped with a quartz cylinder which extends above the bottom of the vessel. This not only protects the edge of the cathode from the cathode spots at the surface of the mercury, but acts as a guide for the mercury vapor and as a sediment trap. The condensed mercury in returning to the cathode does so outside the cylinder; any foreign matter, being lighter than mercury, floats on top and remains outside the cylinder. In returning to the cathode the stream of mercury is broken up by an insulated baffle suspended from the cylinder and thus is prevented from bridging the cathode insulator. This arrangement is shown in Fig. 3.

The scheme of excitation used is shown in Fig. 5. By using a copper oxide rectifier, the advantages of a d-c starting and excitation system are obtained, without the objectionable features of a rotating device. Before the arc is struck, practically the full potential is applied to the solenoid which depresses the ignition rod into the mercury. After the arc is drawn, the resistor in series with the ignition rod causes the greater part of the voltage to be impressed upon the excitation anode and the greater part of the excitation arc immediately transfers to that anode, without the provision of a separate supply. By properly designing the excitation supply equipment, ample voltage is available for the operation of the solenoid without a prohibitively high current or losses in the resistor after the arc is struck. The value of resistance and the characteristics of the copper oxide rectifier are so coordinated that a final current of less than 3 amp in the starting rod and 10 to 15 amp to the excitation anode is obtained. By the addition of the excitation anode a source of ionization is brought close to the anode shield opening, thereby eliminating any hesitancy to "pick up."

When the load on a rectifier suddenly is increased to a high value, voltage surges tend to appear. For any given load on a rectifier there is a given condition of vapor flow, vapor density, and ionization. Before the vapor density and ionization have had time to build up to the requirements of the heavy load, the arc tends to be unstable and the fluctuations in the conductivity of the arc, together with the inductance of the circuit, generate the overvoltages. Since the source of these surges is the arc path between anode and cathode, their prevention is accomplished best by connecting capacitors between each anode and cathode to compensate for the variations in the conductivity of this path. Although it is not necessary for surge prevention, low valued resistors are connected in series with the capacitors to smooth out the voltage wave and avoid objectionable harmonics.

Because a rectifier requires a highly evacuated vessel, and one containing only pure mercury vapor, the manufacturing technique differs radically from that usually employed in the construction of electrical machines. Extreme cleanliness must be practiced during the processes, and many of these processes must be carried out in a conditioned atmosphere. The accomplishment of a satisfactorily tight vessel has been aided greatly by modern welding methods. It is obvious, of course, that a reliable insulating seal is necessary for both anodes and cathodes. However, several types of insulating seals are now well known, any one of which is sufficiently reliable. The choice of seal used is thus a matter of manufacturing convenience and cost. Seals used in the rectifier described here are the soldered-to-porcelain seal at the anodes, and a steel-protected rubber gasket at the cathode. A similar type of rubber gasket is used between main tank and cover.

Even with the best manufacturing technique, the construction of a nearly perfect metal vacuum tank is a difficult problem; and the difficulties multiply with size of tank. Herein lies an important advantage of the sectional rectifier: Not only is the size of tank small for a large capacity rectifier, but also the standardization upon one size always makes for higher quality and greater uniformity of product.

Auxiliaries

The system of auxiliaries used incorporates several unique features. The mercury vapor vacuum pump is of the multi-stage type, which is capable of pump-

ing against a high back pressure. This high back pressure capacity permits the use of a barometric seal, which consists of a tube of barometric length with the lower end immersed in a pool of mercury; in case of any accident to the vacuum system, this arrangement acts as a perfect automatic valve and prevents admission of high pressure gases into the rectifier vessel. This barometric seal is incorporated in the interstage reservoir between the low and high pressure pumps, which permits intermittent operation of the high pressure pump. This pump consists of a rotary oil-sealed pump of small size directly connected to a 1/4-hp motor. Because of the absence of gearing this pump is almost noiseless, and because of its small size the losses are low. However, the capacity is ample for the service required as is evidenced by the fact that in practice this pump is required to operate only from a few minutes per day to a few minutes per week depending upon how long the rectifier has been in service. The starting and stopping of the pump is controlled by a mercury manometer connected to the interstage reservoir. Since the pressure at which this pump starts is well below the maximum back pressure against which the mercury vapor pump will operate, a rise of pressure in the rectifier tank, with the resulting damage caused by operation under this condition, is not permitted.

The valve between the interstage reservoir and the rotary pump operates on a float principle and, therefore, is automatic without requiring any electrical connections. When the rotary pump stops, atmospheric pressure drives the oil back through the pump until enough accumulates in the valve to raise the float.

Pressure in the rectifier is measured with a manually operated gage of the McLeod type and also with a hot-wire instrument; the latter is connected to the control system for protecting the rectifier against operating under excessive pressures. This gage is not used to control the starting of the rotary pump because it is believed that operation of the rectifier with a pressure sufficiently high to operate this instrument is objectionable if continued for a long time. All pressure measurements are made at a connection to the tank separate from the pumping connection. At the low pressures being considered, there is a considerable variation in pressure along even relatively large passages. Therefore, a measurement made on a pumping section at some distance from the tank may indicate a pressure a great deal lower than actually exists in the tank. In the construction of the McLeod gage, a compressible chamber is used instead of the usual barometric tube, with a resulting reduction in length of more than 50 per cent. The hot-wire gage is of the familiar type, but has improvements in compensating features which reduce the effects of the various factors influencing its calibration.

Application

With sectional construction the possibility of operating with part of the units out of service radically reduces the amount of spare capacity required in a high capacity installation. The manner in which the rectifier sections are assembled is quite flexible and is determined by the type of service required. In the rectifiers being supplied for the New York City Board of Transportation the sections are assembled in a truck type frame, and each section is made complete in itself with its own vacuum and water control systems. It is equipped with truck type contacts and flexible water connections so that one section can be disconnected in a few seconds, and the remainder of the unit continued in operation. This complete flexibility, of course, is obtained at the expense of increased cost and increased number of auxiliary parts with the inevitable increase in such troubles as originate in auxiliaries. However, the auxiliaries have been made so reliable that trouble from this source is not serious. Where extreme flexibility is not required, it is just as feasible to connect the rectifier sections to a common manifold with one pumping system, in which case the number of auxiliaries is essentially the same as for a single tank unit.

Since iron is the only inexpensive metal that does not react with mercury, metal tank mercury arc rectifiers are constructed of steel; this, together with the requirement for water cooling, introduces a corrosion problem. When water of the quality usually available is used directly, the rectifier must be designed so that all water spaces are accessible for cleaning and surfacing with corrosion resisting material; this maintenance must be performed at relatively short intervals. Another, and probably better, way of solving the corrosion problem is by providing a recirculating cooling system. This system may be either a water-to-water heat exchanger or a water-to-air heat exchanger. In either case the recirculating water may be such as to eliminate practically all corrosive action. The recirculating system may be either grounded and insulated from the rectifier, or connected directly to the rectifier and insulated from ground with rubber hose, depending upon convenience where installed. It is necessary, of course, that the temperature be controlled accurately. This is not a serious problem, however, for several types of direct-acting temperature-regulating water valves are available, and the control element is

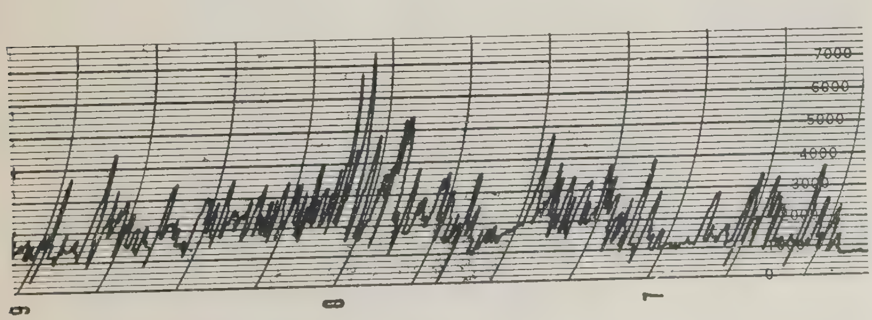

Fig. 7. D-c load chart of rectifier at the Cedar Manor substation of the Long Island (N. Y.) Railroad when operating with only 2 sections in service

placed in the location of most rapid temperature change to avoid the overheating of any part before action takes place.

Mercury arc rectifiers are particularly adaptable for automatic or semi-automatic operation since the control and protective devices required are relatively simple. The degree of protection required depends upon the service to which the rectifier is applied; in many cases this can be reduced to provisions for: clearing a short circuit or arc back; preventing operation with excessive pressures due to a fault in the vacuum system; and preventing operation with excessive temperatures due to a fault in the cooling system.

The transformer connection used is influenced by the location where the rectifier is installed. The cost of a 12-phase transformer must be balanced against the additional cost of a harmonic filter to effect an equivalent wave with a 6-phase transformer, where wave form is important. Since both a-c and d-c systems are underground in the New York City Independent Subway System, and the telephone interference problem thus eliminated, a 6-phase transformer is being supplied for that installation because of its greater simplicity.

The rectifier being supplied for the New York City, Board of Transportation, shown in Fig. 1, is rated 3,000 kw at 625 volts. Specifications require that it be capable of carrying 4,800 amp continuously, 7,200 amp for 2 hr, 9,600 amp for 5 min, and 14,400 amp for 1 min. This rectifier has demonstrated its ability to carry the specified loads, not only on the test floor, but also in actual service. Figure 6 shows the arc drop curve of this rectifier, which, of course, expresses the efficiency of the rectifier when the relatively small losses of the auxiliaries are added.

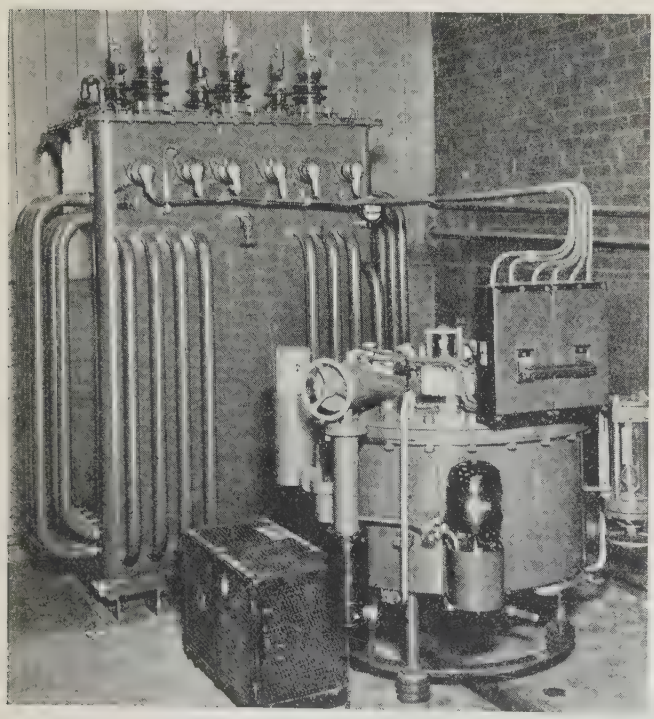

Fig. 8. Rectifier section with transformer having a capacity of 667 amp continuously with the usual overload capacities; 34-in. tank

As mentioned previously, the design of the rectifier described here was based on a conventional design with which a great deal of service experience was available. Three installations were made of this type of design on 3 types of typical railway systems, and in all 3 cases essentially perfect performance was secured during several rectifier-years operation. To date, only one backfire has occurred on these rectifiers. After making the modifications discussed in this paper, in order to make this design suitable for sectional assembly, together with the improvements mentioned, a trial installation was made at the Cedar Manor substation of the Long Island (N. Y.) Railroad Company, early in September 1932. Two of these latest sections, as shown in Figs. 2 and 3, were substituted for 2 of the original sections shown in Atherton's paper (*loc. cit.*) and operation continued on the 2 new sections only. The remaining 2 original sections were kept out of service and maintained only as standby capacity. In this way by operating a station intended for a 3,000-kw rectifier on 1,500 kw of sectional rectifier capacity, a more severe test was obtained, and one more nearly in keeping with the rated capacity of the rectifier. Figure 7 shows a section of a daily load chart taken at this station. It may be seen that during the peak load period the base load averages more than the rated full load of 2,400 amp; upon this the usual short time railway peaks, up to 3 times rated load, are impressed. Up to the date of the present writing, 3 arc backs have occurred; in each case the rectifier was returned to service immediately. In addition to the outages due to arc back several minor interruptions have occurred due to auxiliary and control apparatus, but these have been few and the overall reliability has been equivalent to that required of electrical apparatus in general. Such weaknesses as have been disclosed in the auxiliary apparatus have been corrected. The cooling water consumption at this station has been extremely low. Because of the low load factor of a railway system and the high operating temperature employed, a large part of the losses is dissipated to the room.

Low Capacity Rectifiers

For application on loads of less than 1,250 amp, smaller units have been designed and built following the same general design as that of the sectional rectifier. A typical example is shown in Fig. 8. As would be expected from its smaller size, this unit has demonstrated that it will operate reliably over even a wider range of overloads than will the sectional units. It has a lower arc drop for the same percentage of normal load, as shown in Fig. 9.

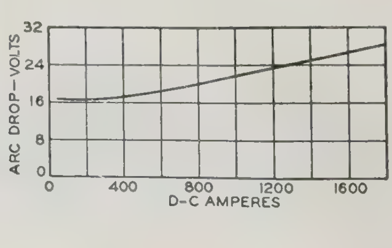

Fig. 9. Arc drop curve of rectifier of Fig. 8

Low Temperature Radiant Heating

This article describes experiments in the heating of a small room by controlled radiation from electrically heated panels in the walls; from the results has been determined a practical method of predicting relative comfort for various combinations of wall and air temperatures. It is claimed that low temperature radiant heating in combination with reversed refrigeration would so lower the operating cost of electric heating as to make it competitive with heating by other fuels.

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A FEW years ago Mr. L. W. Chubb, director of the Westinghouse research laboratories, East Pittsburgh, Pa., suggested the possibility of using electrically heated wall and ceiling areas for creating winter comfort indoors. Based upon his observation of the importance of radiant energy on the human body's sensation of warmth in such instances as sunshine through clear, cold mountainous air, or the flash of radiant energy through a train window from a pile of burning ties, he conceived the idea of making radiation a more important factor in producing comfort conditions. Reducing the idea to practice in occupied space involves the use of large surfaces at relatively low temperatures such as 80 to 120 deg F.

At the research laboratories of the American Society of Heating and Ventilating Engineers it has been found that the average person engaged in ordinary sedentary occupation loses heat at the rate of approximately 400 Btu per hour.[1] This heat is dissipated by radiation, convection, and moisture evaporation from skin and lungs. Mr. L. B. Aldrich[2] has found that in ordinary winter conditions indoors 46 per cent of the body's total waste heat is radiated, 30 per cent is convected, and 24 per cent disappears as latent heat of vaporization.

The body's internal temperature is normally 99 deg F, but the temperature of the outside surfaces of both exposed skin and clothing from which radiation and convection take place is about 80 deg F with variations above and below according to surrounding conditions and clothing worn.

If the walls, ceiling, and floor of a room were at a temperature of 80 deg F, no heat would be lost by radiation from a person within the room. However, health and comfort demand that the heat generated by the ordinary processes of life, which is more or less constant under given conditions, be dissipated; hence, if radiation be prevented, convection or moisture evaporation, or both, must be increased.

It is possible to heat certain portions of solid enclosures so as to obtain partial or entire nullification of body radiation. Under such conditions the room air temperature should be lowered to restore the balance between heat generated in the body and its dissipation.

Many combinations of warmed enclosures with varied air temperatures have been investigated in a room (see Fig. 1) especially designed for studying air conditioning problems at the plant of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. This room, with internal dimensions of 12x16x8.8 ft, is built within one of the standard research laboratories rooms so that there is a space between the walls and ceilings of the 2 rooms from 18 to 24 in. in width. This permits a temperature variation in the air surrounding the experimental room as well as ease in making various adjustments in power supply, air flow, etc. Figure 2 shows the heating units used in the wall and ceiling construction; each unit is 4 ft long and $1^1/_2$ ft wide, and was designed for 250 watts at 110 volts. The base of the unit is a standard insulating lath having a thermal conductivity of 0.39 Btu per hour per square foot with a gradient of 1 deg F per inch of thickness. After these units were nailed to the joist and studding, a finish coat of plaster was applied producing a smooth inside surface to which several coats of enamel were applied to prevent air from passing through the walls. All joints and floor cracks were sealed carefully with linoleum cement so that the air supply to and from the room could be accurately controlled and measured.

Air was drawn from outdoors through a duct above the ceiling and distributed in the room by means of the center ceiling duct shown in Fig. 1. This duct, running along the entire length of the ceiling halfway between the sides of the room, delivered cold air laterally, that s, parallel with the ceiling so that the overall effect was a complete diffusion of the incoming air with the air in the room. Exit ducts were placed in the walls near the floor. The air flow was measured carefully both at entrance and exit by means of nozzle and orifice meters, with an inclined draft gage used to indicate equal pressures between inside and outside atmosphere. A centrifugal blower with speed control operating in the entrance duct and a suction fan in the exit duct were so operated as to eliminate pressure differences between the inside and outside atmosphere, thus eliminating as far as possible any air leaks.

Copper-"advance" thermocouples with the warm junction soldered to a patch of copper screen just under the finish coat of plaster were led out along isothermal surfaces to the edges of each heating unit

Full text of a paper "Obtaining Comfort Conditions by Controlled Radiation from Electrically Heated Walls" (No. 33-78) presented at the A.I.E.E. summer convention, Chicago, Ill., June 26-30, 1933.
1. For all references see bibliography.

Fig. 1. One side of the experimental room in which the tests were made

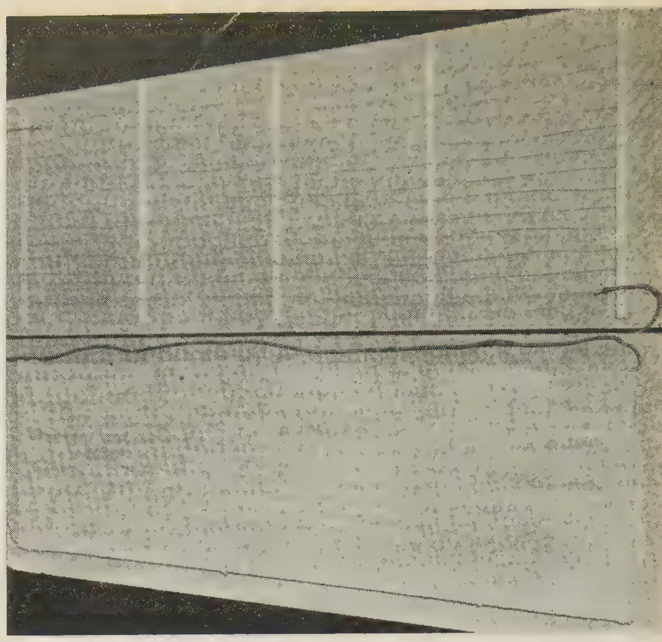


Fig. 2. Two of the electrically heated panels, the upper one before and the lower one after imbedding the resistance wires in plaster

and then back through the wall to a multiple switch and potentiometer. Surface temperatures thus were accurately determined. Air temperatures were determined in the ducts as well as in various parts of the room with No. 36 B&S gage copper-"advance" couples. Mercury thermometers also were used, mainly to see how far their indications deviated from true air temperatures under various conditions of warm walls and cool air.

Preliminary work showed quite definitely that not only can comfort conditions be obtained with 80-deg walls and 60-deg air, but also that such environment is highly invigorating. The cool air is quite acceptable when one at the same time feels entirely comfortable. However, to maintain the air at 60 deg within 80-deg walls, it was necessary to introduce fresh cold air into the room at a rate of from 6 to 10 changes per hour, depending upon the temperature of the air fed into the room. It becomes apparent at once, therefore, that heating enclosing surfaces of ordinary living rooms to 80 deg F uniformly is out of the question. Since normal infiltration changes the air in a house from 1 to 3 times per hour, it was decided to limit these studies to such an air flow with but portions of the enclosing surfaces heated.

Altogether 104 units were used in the walls and ceiling connected two in series across the power supply lines through an "on" and "off" switch for each pair. Power was controlled with a voltage regulator. Thus the position and extent of the heated wall or ceiling area, as well as its temperature, could be varied at will. A master switch in series with an adjustable thermostat and wall meter mounted inside the room completed the electrical equipment.

A single observation required about 60 individual readings for a complete picture of the effect of any one set of conditions. The aim, of course, was to examine a sufficient number of conditions to predict comfort and power requirements for any conditions where low temperature radiant heat is to be used. In Table I the data of 10 typical observations are summarized.

Discussion of Results

For purposes of estimating power requirements in any applications using this type of heat and also for the purpose of having a check on air flow and power input, it was thought desirable to account for all the power used. Items 18 and 19 of Table I show how closely this was done. The thermal conductivity of the walls was tested accurately so that the dissipation through the walls could be determined fairly accurately with a sufficient number of inside and outside temperatures. Failure to obtain enough outside temperatures for observations 1 and 4 resulted in the loss of this estimation. Another source of inaccuracy in this regard was the inability to obtain an accurate average entrance air temperature. Some of the heat within the test room passing through the ceiling served to supply part of the preliminary temperature rise of duct air while the rest was drawn from the space and building around the room.

It is a difficult matter to predict accurately the effects of temperature, position, and orientation of the heated panels on an occupant of the room, even though he might stand erect in the center of the room. The radiant flux to a person in the panel heated room is, of course, a function of: the solid angle, temperature, and orientation of the heat source; and the outside area, temperature, and position of the recipient. It would not be a simple

matter to compute accurately the integrated solid angle of all room surfaces integrated in turn over the person of the occupant with due regard for orientation of both person and walls. A rough measure of comfort, however, has been computed; this has been added as item 26 at the bottom of Table I under the caption "comfort index."

To obtain a value of the comfort index for each set of conditions a cylinder was postulated in the center of the room having radiating and convecting surfaces approximating those of the average man with the same general shape and size as regards volume. It was assumed for instance that there were 20 sq ft of convecting surface and 16 sq ft of radiating surface with an emissivity of 0.9 for the temperatures under consideration.

The equation for convection from such a vertical cylinder was taken as $H = 0.35\ \theta^{1.25}$ where H is expressed in Btu per hour per square foot of surface and θ is surface temperature rise in degrees F. Figure 4 shows the loss based on this equation in Btu per hour from a vertical cylinder with a uniform surface temperature of 80 deg F to air at temperatures under 80 deg F. Figure 3 shows the radiant interchange of heat between the assumed cylinder and its solid surroundings in Btu per hour.

After these curves were drawn they were checked by applying standard conditions, that is, the body heat loss with air at 70 deg F and walls at 68 deg F was found by the use of these curves to be 300 Btu per hour, which is approximately correct according to the previously cited work done at the American Society of Heating & Ventilating Engineers research laboratory. The negative sign before the comfort index (item 26) in Table I indicates a loss by radiation and convection from the cylinder of the specified number of Btu per hour for each case. Thus −300 Btu per hour would indicate comfort while −447 would indicate a chilly condition and −64 a much too warm condition. No great accuracy is claimed for this system, but it is presented as the best available at this time. It must be borne in mind that if this cylinder should wander over toward one of the heated wall panels, thus subtending a greater solid angle of warmth, these comfort indices would not apply as accurately as if it stayed in the center of the room.

The curves developed, as a result of the work described here, were tested by applying some recent results obtained at the research laboratory of the A.S.H.V.E.[3] Three walls of a 5x6x6-ft room there were cooled while the air temperature was raised until comfort was obtained. One point of the A.S.H.V.E. comfort curve gave the temperature of 3 walls at 45 deg F with air at 78.9 deg F. The comfort index computed by the method here developed for such a condition is −284. If the floor, ceiling, and fourth side wall had been assumed at a temperature slightly lower than that of the air, the index would have approached very nearly the ideal of −300. Since the room was so small it was more easily possible to take into account the solid angle and orientation of surfaces, which also raised the computed radiation losses. It is believed, therefore, that the method developed for predicting comfort conditions in radiant heated spaces is satisfactory for all practical purposes.

The method of using these curves is simple enough as is illustrated in the following example:

Let area of total enclosure surfaces be 878 sq ft. Assume:

96 sq ft of ceiling at 107° F
96 sq ft of ceiling at 66° F
84 sq ft of walls at 101° F
410 sq ft of walls at 67° F
192 sq ft of floor at 69° F
Air temperature...... 67.5° F

From the radiation and convection curves we have:

Radiation

96 sq ft at 107°	= +460 ×	96	=	+44,100
96 sq ft at 66°	= −202 ×	96	=	−21,000
84 sq ft at 101°	= +351 ×	84	=	+29,500
410 sq ft at 67°	= −195 ×	410	=	−80,000
192 sq ft at 69°	= −165 ×	192	=	−31,500
		878	=	−58,900

Table I—Summary of Data for 10 Typical Observations

1. Observation No.	1	2	3	4	5	6	7	8	9	10
2. Outside air temp. (° F)	32.2	33	16.7	29.7	46.5	37.6	44.3	43.7	36.7	20.4
3. Air changes per hour	1.15	1.18	3.1	3.3	6.1	3.2	3.3	3.2	2.1	2.1
4. Temp. of entrance air (° F)	55.0	56.0	33.5	49.4	53.3	48.3	55.4	55.9	54.1	43.3
5. Temp. of exit air (° F)	66.3	64.0	59.3	68.6	66.0	68.2	71.4	74.1	69.1	67.8
6. Temp. rise of air in room (° F)	11.3	8.0	25.8	19.2	12.7	19.9	16.0	18.6	15.0	24.5
7. Temp. of air surrounding room (° F)	...	58.0	44.0	...	61.4	60.0	65.6	65.8	63.1	57.6
8. Area of heated ceiling (sq ft)	192	192	144.0	144.0	96.0	96.0	96.0	96.0	96.0	96.0
9. Temp. of heated ceiling (° F)	82.3	78.4	87.5	105.1	96.0	95.3	91.2	104.4	89.1	107.1
10. Area of cold ceiling (sq ft)	...	...	48.0	48.0	96.0	96.0	96.0	96.0	96.0	96.0
11. Temp. of cold ceiling (° F)	...	...	60.0	69.5	66.8	66.9	70.9	73.0	67.9	66.3
12. Area of heated walls (sq ft)	36	36	36.0	36.0	84.0	102.0	84.0	84.0	84.0	84.0
13. Temp. of heated walls (° F)	81.2	77.2	90.0	111.6	95.0	97.0	90.8	103.9	103.9	101.2
14. Area of cold walls (sq ft)	458	458	458	458	410	392	410	410	410	410
15. Temp. of cold walls (° F)	62.7	66.0	60.0	68.5	67.0	66.3	70.4	73.7	68.8	67.2
16. Watts lost through walls	...	1,076.0	1,876	...	919	1,440	1,057	1,457	1,007	1,932
17. Watts lost to air	114	83.0	700	575	690	570	475	527	280	462
18. Total dissipation (computed)	...	1,159	2,576	...	1,609	2,010	1,532	1,984	1,287	2,394
19. Watts input meter reading	1,200	1,200	2,100	2,500	1,800	2,400	1,450	2,200	1,400	2,900
20. Watt density (watts per sq ft)	5.3	5.3	11.6	14.0	10.0	12.1	8.0	12.2	7.8	16.1
21. Avg enclosure temp	68.9	65.0	66.1	76.7	73.0	74.0	75.1	80.2	73.2	75.4
22. Avg air temp., thermocouple	66.0	63.0	59.2	68.4	66.0	68.3	70.4	73.7	68.8	67.5
23. Avg air temp., mercury thermometers	...	64.0	...	70.0	68.0	70.0	72.7	76.0	70.7	70.3
24. Per cent of ceiling area heated	100	100	75	75	50	50.0	50.0	50.0	50.0	50.0
Per cent of side wall area heated	7.3	7.3	7.3	7.3	17.0	21.0	17.0	17.0	17.0	17.0
25. Per cent of enclosure surface heated	26.0	26.0	20.5	20.5	20.5	22.6	20.5	20.5	20.5	20.5
26. Comfort index	−353	−447	−516	−189	−285	−232	−187	−64	−240	−226

Dimensions of room, 12x16x8.8 ft. Inside areas in sq ft: ceiling, 192; floor, 192; side walls, 494; total, 878. Space, 1,690 cu ft.

and the average is $\frac{-58,900}{878} = -67$

Convection for air at 67.5 = −160
Total dissipation = −227.
Data for these figures were taken from observation No. 10.

One of the outstanding features of this heating method as observed in the experimental work described here is the remarkable uniformity of air temperature throughout the entire room. The fine-wire thermocouple used to explore various parts of the room indicated air temperatures not differing more than a degree from each other. As an example, details of observation No. 6 show temperatures in degrees F as follows:

6 in. below ceiling center of room	69.1
Breathing line	68.8
6 in. above floor	68.2
Front left corner 14 in. above floor	68.2
At breathing line for one seated back of desk	69.2
Right side near bookcase thermometer	68.1

The floor was covered with a chenille carpet the temperature of which, after equilibrium conditions were established, was from 2 to 3 degrees higher than that of the air.

From an examination of Table I it is apparent that conditions represented by observations 1 and 5 come nearer to fulfilling comfort requirements than any of the others, their comfort indices being respectively, −353 and −285; however, No. 1 is too cool, and No. 5 is too warm. For No. 5 the air temperature is 7 deg F lower than the average enclosure temperature. It may be pointed out also that by raising the average enclosure temperature some 5 deg above that usually prevailing for ordinary heating methods, the air temperature is lowered 4 deg in this particular instance and should have been lowered another degree for ideal conditions.

In general, no effort was made to find the optimum conditions for the greatest number of people, but comfort always was aimed at and with 2 exceptions (observations 5 and 12) the room was not extremely uncomfortable for any of the conditions recorded in the Table I.

The method of using rather extensive areas at moderately low temperatures has been given more study in Great Britain than in this country. Several references relative to this so-called panel heating are included in the bibliography (references 4 to 15, inclusive).

Humidity was neglected in this work because its effect on human comfort at a dry bulb temperature of less than 70 deg F is not so important as it is at higher temperatures. (See American Society of Heating & Ventilating *Guide* for 1931, p. 409, for curve of heat and moisture losses as functions of the dry bulb temperature.) In fact one of the advantages of cool air and warm walls is that not only is the relative humidity naturally higher, but its effect as a comfort factor is much less important than it is for warmer air.

Electric house heating is attractive because it is clean, easily controlled, and requires no labor for operation. It is expensive at present power rates and method of application, but this low temperature radiant heating suggests a possibility of lowering costs. The normal power requirements for straight electric resistance heating is 1.2 to 1.5 kwhr per cu ft of space heated per heating season of 212 days (Oct. 1 to May 1) based upon: 40 deg F average outdoor temperature; infiltration of one change per hour; and ordinary brick veneer wood frame, lath, and plaster construction. This figure no doubt could be reduced by insulation, and by close night and day regulation with lower temperatures at night. Panel heating offers some additional saving in straight resistance heating because it is unnecessary to warm the air quite as much where radiation plays a greater part. But this low temperature wall heat will make a tremendous difference if reversed refrigeration becomes generally used. By pumping heat from the outside to a moderate temperature of say 80 deg F, the coefficient of performance of the heat pump is much higher than if this heat were to be pumped in at a temperature of 180 deg F. In

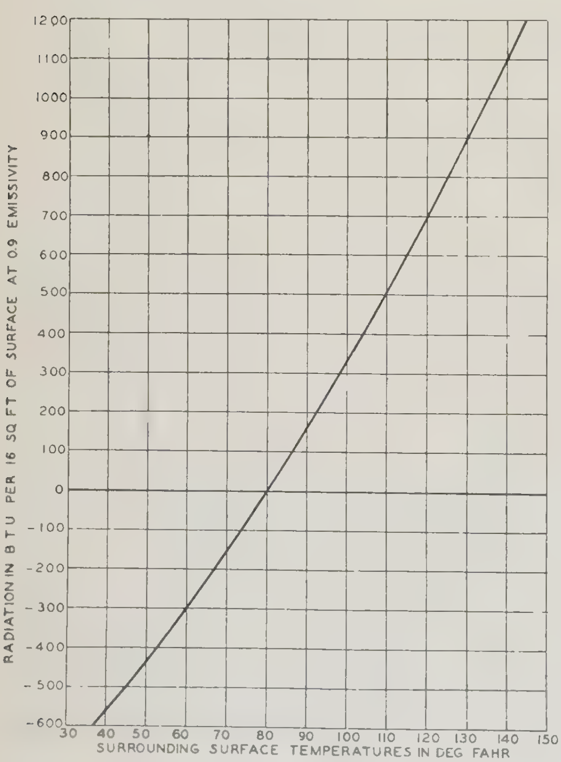
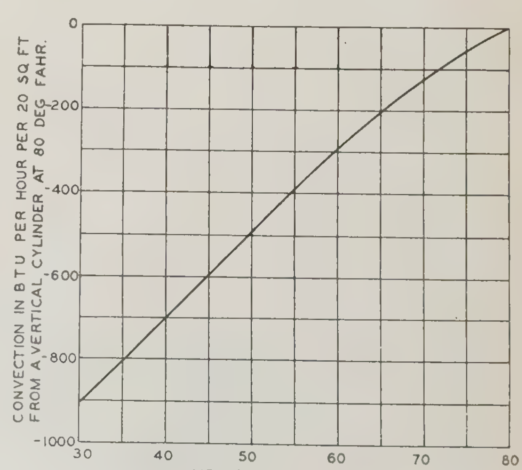


Fig. 3. (Left) Radiation from a vertical cylinder having the approximate size and shape of an average man, with the outside temperature maintained at 80 deg F

Fig. 4. (Right) Convection from a vertical cylinder having the approximate size and shape of an average man



fact with one-cent power and reversed refrigeration operating between 40 and 80 deg F, the actual operating costs become competitive with coal.

Even with present power rates electric wall heating should be applicable to warmer climates where the necessity for heat occurs only an hour or so in the mornings and evenings during the winter season. The type of wall units described here can be made quite inexpensive so that the cost of equipping an entire house would be but little more than the cost of ordinary lath and plaster.

Summary and Conclusions

Briefly summarized, the important findings of this investigation and conclusions reached are as follows:

1. The results of observations on space heating with rather extensive surfaces at moderately low temperatures have been worked into a practical method of predicting comfort with various combinations of wall and air temperatures.

2. The air temperature may average from 2 to 8 deg lower than the average enclosure temperature, which results in a saving of heat.

3. Most of the radiating surfaces were put in the ceiling; this seems to be desirable to cut down heat losses, and is not objectionable from the standpoint of comfort. It no doubt would be desirable to put warm panels in selected places in the side walls, as, for instance, under windows to prevent downward air currents and nullify to some extent the body's radiation to the cold window surfaces.

4. A remarkably uniform temperature was found to prevail within the room as a result of the heating method here presented.

5. The low temperature radiant heating method in combination with reversed refrigeration would lower the operating costs of electric heating to a point where it might be competitive with heating by gas and oils or even coal.

6. Power consumption varied from 5.3 to 16.1 watts per sq ft. It is possible that a 2-range provision might be made with a density of 50 watts per sq ft for accelerated effects on a cold morning for a few minutes after the power is turned on, and $^1/_4$ of that density for steady application. Where 1 sq ft of heated area is used for each 10 cu ft of space heated, $12^1/_2$ watts per sq ft should be ample for quite severe weather. Modifications in outdoor temperature could be taken care of with a thermostat set to throw the power on or off according to requirements.

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Staged Tests on High Speed Relays

Staged tests on high speed distance relays involving the placing of artificial short circuits on high voltage transmission lines not only eliminate much of the low voltage testing, but give a more complete check on the functioning of apparatus. Planning and procedure of staged tests are discussed in this article.

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TESTS of high speed distance relays consist either of low voltage tests or staged tests. The latter involve the placing of an artificial short circuit on a high voltage transmission line, and observing the operation of the various pieces of equipment. Staged tests, although not frequently used are especially desirable with the new high speed relays, due largely to the increased complexity of these relays as compared to the older relays.

Low Voltage Versus Staged Tests

Low voltage tests are adequate for the following purposes: locating loose connections, locating broken leads, checking polarity, measuring resistance, testing insulation resistance, checking reactance indication, investigating performance of contacts as to sticking or sparking, checking timing, and otherwise determining the mechanical and electrical condition of the individual elements of the relays themselves. There are serious objections to depending on the results of low voltage tests alone as a check on the satisfactory operating performance of a protective installation. Staged tests will do almost everything that can be done by low voltage tests, and in some cases the low voltage tests may be unnecessary, provided the staged testing is carefully planned. In any case, much less low voltage testing needs to be done if adequate staged tests are made.

Complete low voltage tests require more equipment than staged tests. On distance relays a large amount of time is required to phase out the connections of the low voltage test equipment. In fact this may require more time than a staged test. In many cases the range of variation of electrical quantities on

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low voltage tests is rather limited compared to the various possibilities with staged tests. Low voltage tests give no check on selectivity, current transformer performance, potential transformer performance, and may not give any check on bell alarm schemes or on interlocks. Staged tests will give a check on the accuracy of calculations, phase markings, line constants and other system data used in short circuit calculations, speed of circuit breaker opening, adequacy of potential supply, breakdown in ratio of bushing current transformers, performance on 2-phase to ground short circuits and other conditions difficult or impossible to calculate.

Planning Procedure for Staged Testing

Much of the description given below is common to all staged tests of high speed distance relays on transmission systems, but is given in view of the lack of published information on the actual procedure. The value of the results obtained from staged testing is very largely dependent upon the time and skill available for working out the test procedure. Staged tests on any system become more important and valuable from year to year, because the experience obtained in previous tests can be utilized as a basis for planning future tests.

The risk to equipment is negligible. Staged tests of all kinds have been carried on on this system for 8 years. Interruptions to service on account of staged tests have been negligible.

Very little information is available from manufacturers on staged testing. On account of the need of time to make plans for staged tests, it is desirable to plan these tests at least one week ahead of time if possible. In emergency, staged surveillance tests of limited scope have occasionally been run on less than 12 hours' notice, but conditions are not always such as to permit this procedure. The certainty, accuracy, and utility of the results will be more or less directly proportional to the time spent in planning. Procedure in arranging for staged tests will usually follow more or less the following outline:

1. Determine scope of tests.

Determine the general scope and extent of the tests. This really amounts to listing the questions to be answered by the tests and determining the emergency operating conditions which should provide the answers to these questions.

2. Arrange for service interruptions.

Make arrangements with the commercial departments or others concerned for permission to interrupt customers by appointment, or if there will not be any interruptions, investigate the effect of surges or voltage variations and get the consent of those concerned. If tests are to be made on the high voltage system, it is well to notify interconnecting companies.

3. Cooperate with communication organizations.

Unless all the tests are to be phase-to-phase short circuits, and there is no possibility of accidental or intentional faults to ground, all communication companies likely to be affected by ground current should be notified. While this can sometimes be done on short notice, it involves considerable expense and loss of time to stop field crews and have them wait until the tests are over, and it is much better to have other work planned for them a few days ahead of time.

In a few cases involving main toll routes it may be impossible to re-route all traffic except late at night or on Sunday. Occasionally where induction is expected the telephone company will have the operators turn down the lines against traffic. This considerably complicates the test schedule and generally results in making it very difficult to get through long distance calls for dispatching or to communicate with the telephone test board. It is therefore desirable to insist that the telephone company either re-route affected lines, or notify the power company dispatcher before turning them down to traffic.

The communication companies will frequently desire to make tests of their own at the same time the power company is testing and are usually willing to interchange data and observations. This is of considerable assistance to the power company, especially in case of the telephone company, since the Bell System generally makes available considerable oscillographic equipment and trained observers, and it may provide facilities for measurements that the power company cannot easily handle.

As will be noted from the above suggestions it is vital that the operating department of the power company work in close cooperation with the plant departments of all affected communication companies in planning and executing the tests.

Needless to say, the same notification should be given the telephone department of the power company.

4. Consider power system load conditions.

In many cases the schedule for the tests will be governed by load conditions on the power system. Certain tests may not be economically practicable except under certain generating and load conditions, and the tests should be planned far enough ahead to permit them to be carried out successfully with the minimum additional expense for power.

5. Testing advantageous at time construction is completed.

As nearly as possible the starting of staged tests should be synchronized with the completion of construction. Testing before construction is completed is likely to be a waste of time, since there is no assurance that control wiring may not be changed. If construction is completed before testing is begun, major equipment should not be cut in service until protective equipment is completed and finally tested. The arrangements that held during construction should be maintained until testing is completed. Cutting in power equipment or lines initially without protection or with untested protection results sooner or later in serious trouble for the relay department, including lack of confidence in personnel and equipment. With these factors in mind it is usual to plan installation testing to begin immediately after construction is completed, allowing some time for unexpected delays in completing construction. If the construction crew is released before testing is done, it is generally advisable to keep at least a switchboard wireman so as to change control wiring as required to get correct phasing. Some companies do not put up meter and relay connections permanently until after final tests, but this has the disadvantage that it is difficult to complete these connections in a permanent manner during the tests, and if the work is done later it cannot be checked. Every effort should be made to have all control changes completed before or during testing, so that there is a minimum possibility of unsupervised and untested changes afterward.

6. Predict fault currents.

The approximate magnitude or limits of expected fault currents should be determined by calculation or on a short-circuit table, and furnished to the test men. These data will determine the ranges of oscillograph shunts, the ratios of current transformers, potential transformers, and indicating meters.

7. Secure good ground connection.

The faults should be placed at a location where there is a good ground connection, if ground faults are to be made, or if there is any possibility of accidental faults to ground. Where this precaution is not available it is necessary for all observers to keep possibly 100 ft away from the fault, and avoid any connection of instruments in the circuit between the fault and ground. Where good ground connections are provided, the ordinary insulation in instruments and control leads is sufficient against the rise of ground potential, and there is no danger to observers unless the ground lead is touched. It is good practice to make ground resistance tests with a ground megger and to see that all grounds at the point of test are solidly tied together and are of sufficient conductivity that they will not burn open.

8. Maintain company communication facilities.

Arrangements should be made to preempt the communication facilities needed for dispatching during the tests, and other departments should be given sufficient notice, so as to incur the minimum inconvenience to routine traffic on the company telephone lines. If this is not done considerable expense and unsatisfactory test results are likely to result from delays in switching caused by lack of communication. Without constant communication any incorrect

relay operations or unexpected difficulties may interrupt service to customers, and it is therefore desirable that points involved in switching and testing should have 1 and preferably 2 means of communication at all times during the tests. It is generally desirable to maintain telephone communication between all points affected, for several minutes before and after each test. This also facilitates getting a prompt record of the test results and restoring service quickly. However, on ground tests the company telephones may have to be disconnected by opening the entrance switch, if induction is unusually heavy and if communication during the fault is not absolutely required. It is also desirable to have a telephone man pull the carbon blocks on the telephone protectors if the rise of ground potential is above that required to ground the carbon blocks but below the flashover point of the rest of the inside wiring. In synchronizing test procedure between distant points without communication, telechron clocks with second hands are of great service.

9. Arrange for personnel necessary.

The personnel present at the scene of the test or at strategic points on the system will naturally vary with the nature and extent of the tests, but in general there should be men present to read the test instruments, operate the oscillograph, develop films, handle dispatching, make calculations (in case of unexpected set-ups), check relay performance, make permanent changes in wiring, and keep the communication equipment working. The relay engineer or the head of the system operating department is likely to be in general charge of the tests and is generally present at a point where he can keep in close contact with the dispatchers and with the relay men. If some of the functions mentioned are handled by other departments, it is desirable to have a department head or supervisor from each other department available at the same point, so that decisions can be promptly made and carried out.

The relay engineer should have available general system short-circuit data, wiring diagrams, instruction books, relay settings, and all the necessary information to check the results of the tests as they are obtained, and to modify the schedule of tests as required in order to obtain the most valuable data.

10. Various types of artificial faults.

On most relay tests it is desirable to observe the performance of the relays under all fault conditions: single phase to phase, 3-phase to phase, single phase to ground, and 2-phase to ground. On distance relays one of the surest tests of correct phasing and connections is for the relays to clear a distant fault in the same time for both single and 3-phase conditions. (This assumes delta connections of current transformers.) On distance relays it is carbonized. Furthermore, tests involving rope without other insulation cannot be made except in dry weather. Where the fault can be placed on the line by closing an air break switch or oil switch either a solid fault or arcing fault can be provided. Solid faults were at first favored as being somewhat quicker and easier to handle, but we now use arcing faults almost altogether. Arc faults can be started by fuse wire, wet rope or cord (preferably soaked in salt water), or by small copper wire. If copper wire is used, calculation should be made to be sure it will fuse quickly enough for the purpose of the test. The arc from a fuse has the advantage that it will clear as soon as power is removed. Air break switches are not seriously burned by closing on to faults but of course should not be opened unless the fault clears. At 110 kv arc faults around 20 ft can be maintained, although we normally use about 4 ft or the length of an insulator string. At 2,300 volts it is impossible to maintain an arc more than a few inches, but at 154 kv the arc can be drawn out to surprising distances. Dependence therefore should not be placed in separating the arc terminals to put the arc out as it is pretty sure to hang on until the power is cut off. If there is any breeze present the arc is likely to travel a considerable distance, unless it occurs on top of horn gaps or between other isolated high points. Sufficient overhead clearance should also be provided on arc faults as the arc will rise to surprising heights. Unless a ground fault is made, adequate clearance should be provided so that the arc cannot unexpectedly go to ground (and probably interrupt communication). Almost no interference with communication is experienced on straight phase faults. In placing solid faults, conductor of the same size as the transmission line should be used. Ground chains will not stand this service as they arc between links and are likely to burn in two on a single test. The most convenient way of placing single end faults on a transmission line is to place a solid fault across the bus side disconnecting switches of an oil circuit breaker and then close the breaker on to the line. If the disconnecting switches are 6-pole gang operated, the coupling between the line and bus side operating bars can be removed so as to close the line side disconnects.

11. Provide back-up relay protection.

It is well to provide back-up protection so that if some particular circuit breaker fails to operate the fault will not stay on the system indefinitely. It is general practice to block one or more breakers to insure uninterrupted service to important customers during tests, especially since the relays under test are likely to have their time set up to facilitate observation. To permit better observation of the performance of distance relays during fault conditions it is usual to open the trip circuit of the relays being observed if there is another breaker which can clear the fault. It is always desirable

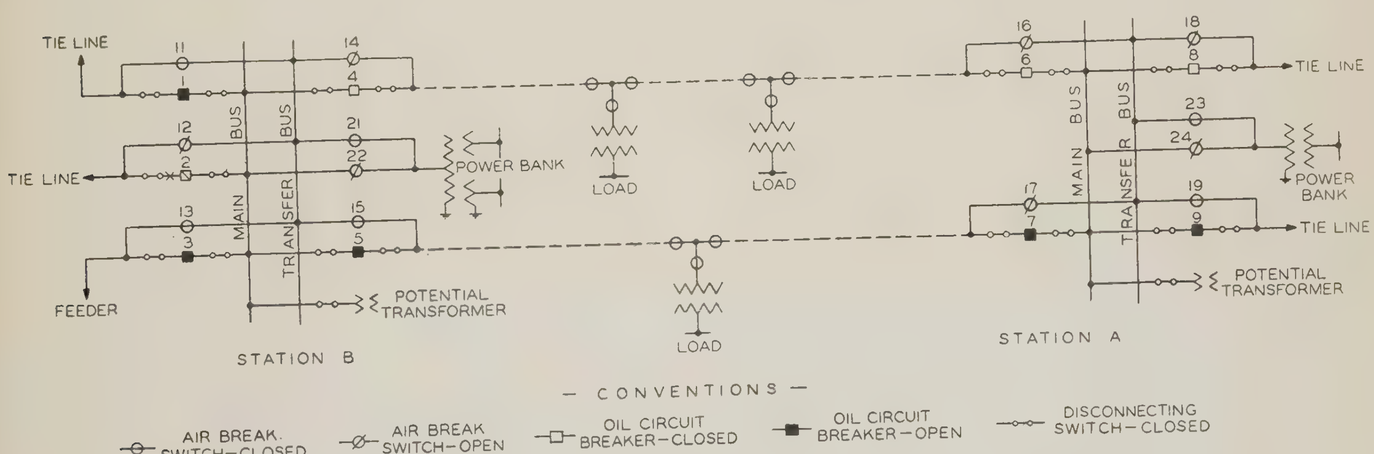

Fig. 1. One line diagram of 2 switching stations, illustrating a typical staged test

also desirable to make tests with power supply from either end and from both ends. This last condition is difficult to meet, unless the line has a tap with a switch in it. So far as we know, there has never been developed any satisfactory means of placing a temporary fault on a hot transmission line with power supplied from both ends, except to close a branch line switch. If fuse wire is pulled across the line with a paraffined rope there is some possibility of damaging the line, unless high speed relays and breakers work perfectly. On moderate voltages, the most successful scheme has been to fasten a copper ring several inches in diameter on the end of each phase of the bus and pull a treated rope through the rings. On one portion of the rope a fuse wire is wrapped between the strands to start the arc. The rope does not last long as it finally becomes

to use first a breaker and set of relays at some other station which has been tested previously to perform the actual function of clearing the short circuit. During these early tests the new relays may be observed to make sure that their phasing, polarity, etc., is correct, after which they may be used to clear the short while the details of their operation are being studied.

12. Time between successive tests.

The usual time between tests will vary from 15 to 60 min (although the writer witnessed a large series of tests on one system run on 5-min headway). It is desirable to notify the communication companies before each test. On development tests it is very difficult to follow a pre-arranged schedule.

Details of a Typical Short-Circuit Test

To illustrate the detailed test procedure in a typical case reference should be made to Fig. 1, which is a one line diagram of 2 switching stations on the Tennessee Electric Power Company's system. Station *B* had been thoroughly tested several months previous while station *A* had just been completed with the switching arrangement shown. Station *B* secured a clearance on circuit breaker 2 and placed a 3-phase short circuit on the line of this oil circuit breaker. The tie line on circuit breaker 8 (station *A*) is a direct tie to a generating plant where it is tied into the system. There are no loads tapped off of this tie line. On the other hand the tie line on circuit breaker 9 has a number of tapped loads some of which are very sensitive to voltage changes. The tie line on breaker 2 has tapped loads but these were supplied from the other end of the tie line by opening a sectionalizing air break switch at the load nearest station *B*. The particular switching arrangement shown is for the testing of the relays on breaker 6. It can be noted that the only customers subject to any severe disturbances are those tapped off of the tie line between breakers 6 and 4. Of course the system was subject to a slight voltage drop in feeding the short circuit by way of tie line 8.

For this particular test the relays on breaker 2 were allowed to operate with their normal settings. After the oscillograph had been started, breaker 2 was closed onto the short circuit and allowed to open by relay. At station *A* the instantaneous elements of the distance relays on breaker 6 were set for a reactance of 110 per cent of the line reactance from station *A* to station *B*. This follows the principle of leeway in that the relays are allowed 20 per cent in their final settings. Their trip circuits were disconnected from the breaker trip coil and instead a resistor arrangement was used so that the relay targets would operate and the time when the relays would have tripped the breaker would be recorded by the oscillograph. The operation of the various elements of the distance relays on breaker 6 was observed during the test while the oscillograph film gave considerable data on the transmission line constants and also recorded the speed of the relays for instantaneous operation.

Since the relays operated successfully on this test the relays on breaker 2 were set so as to give a total time of approximately one sec. The relays on breaker 6 were then set so that their instantaneous elements would operate on a reactance of 90 per cent of the reactance of the line from station *A* to station *B* and their intermediate time elements were set to operate for a reactance 110 per cent of this value. These values allow the same margin over the final settings as before. The intermediate time was set at 60 cycles and the relays arranged to operate the oscillograph only as in the previous test. These special connections of the relays were made by means of test jacks inserted in test blocks permanently installed on the switchboard, so that no part of the permanent switchboard wiring was changed. In this manner the possibility of leaving a set of relays reversed or inoperative after the tests are finished is reduced to an absolute minimum. Breaker 2 was closed onto the short and allowed to relay as before. During this test, observers read the position assumed by the reactance arms of the distance relays during the short circuit.

Following these tests a similar test was made except that 2 phases of the line were shorted together instead of all 3. The relay corresponding to the shorted phases should indicate the same reactance as it did during the 3-phase short-circuit test (assuming delta connected current transformers). The final check on the distance relays of breaker 6 was made later when an arcing fault was placed at station *A* on the line side of breaker 6. In this case the relays were allowed to trip the breaker. By means of the oscillograph a check was obtained on the accuracy and speed of the relays for nearby short circuits and in addition the performance of the oil circuit breaker could be analyzed.

In testing the relays on oil circuit breaker 8 a short circuit was placed at the far end of the tie line. During the earlier tests the performance of the relays on this circuit breaker had been observed with regard to phasing and polarity by reversing these relays and blocking their trip circuits with test jacks. It was therefore thought unnecessary to arrange for the breaker at the far end of the tie line to clear the short circuit. For these tests station *B* was arranged so that all oil circuit breakers were closed and all transfer bus air break switches were open. At station *A* oil circuit breakers 6 and 7 were closed and 9 was open. Oil circuit breaker 8 was used to close in onto the short circuit. Air break switches 23 and 19 were closed. This arrangement was used in order to supply sufficient short-circuit current for the tests. A good many customers were subjected to a slight drop in voltage but the impedance of tie line 8 acted as a cushion for them.

In testing the relays on breaker 9, it was desirable to cause as little disturbance as possible to the customers located along this line. Consequently for the early tests, air break switches 18, 24, and 19 were closed, and oil circuit breakers 6 and 7 were closed while breaker 8 was open. Breaker 9 was used to close in on the short circuit at the end of tie line 8 by way of the transfer bus at station *A*. Of course an air break switch at the nearest customer on tie line 9 had been opened before the test. After the relays on breaker 9 had been checked in this manner as thoroughly as necessary, the system set-up was changed and an arcing short was placed at the far end of tie line 9. Breaker 9 was allowed to open by relay and to reclose instantly by means of its regular instantaneous reclosing relay. In this manner considerable data on the line constants was obtained by means of the oscillograph, with only one disturbance to the critical customers on tie line 9.

Many expedients may be used where the full switching facilities shown on Fig. 1 are not available. For example, certain makes of 6-pole gang operated disconnecting switches may be made to operate 3 poles at a time by removing one pin in the operating mechanism. At times it is necessary to place a short circuit on the bus side of the oil circuit breaker and reverse the connections of the relays by means of test jacks.

Resuscitation by Countershock

The possibility of recovery of the fibrillating heart has been the subject of extensive experimental work, the results of which demonstrate conclusively that normal rhythmic functioning can be restored successfully in many cases.

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IT IS WELL KNOWN that an electric shock causes muscular contraction, and that this contraction is greater for high voltages than for low voltages. When a small 60-cycle alternating current passes through the heart, experience and experiments show that it apparently is not great enough to inhibit heart action entirely, but sufficient only to destroy the regular, coordinated muscular activity of that organ, with a result that ventricular fibrillation is induced. When the ventricles of the heart go into fibrillation, the activity of the cardiac musculature no longer is coordinated and a cessation of blood circulation results. The human heart as well as certain animal hearts, such as that of the dog, seldom recovers spontaneously from fibrillation. Death, therefore, usually results. Thus, ventricular fibrillation is believed to be one of the principal causes of fatalities in cases of low voltage electric shocks, and of the failure of the victim to respond to artificial respiration.

Experiments have proved definitely that the heart may be thrown into fibrillation by a low voltage electric shock. Strong currents, however, suddenly and momentarily applied, produce sufficient contraction to bring the muscles completely to rest. This pause in heart action may last from a few seconds to about a minute, after which the organ will resume its normal, rhythmic beating.

For some time the authors have been conducting a detailed study of the effects of 60-cycle alternating current upon the dog heart, with particular reference to fibrillation. Funds for the support of this work were made available through the generosity of the committee on physiology of the Conference on Electric Shock. The work was undertaken as an investigation of the suggestion made in Italy[1] in 1899 that ventricular fibrillation does not result when a large current flows through the body, and that if present it can be stopped by the application of a high voltage countershock. That this statement is true is evidenced by the results of the experiments here recorded, which experiments have proved that a suitable electric countershock may be used to resuscitate a heart thrown into fibrillation as a result of an electrical accident, or other causes. All animals used in this investigation were deeply anesthetized with morphia and ether.

Comparison of High Voltage and Low Voltage Shocks

In the preliminary experiments circuits of from 110 to 2,200 volts were available. Contacts with an animal under test were made by means of 2 electrodes soaked in saline solution, one applied to a shaved area on the head and the other either to the tail or hind leg. In a series of 7 experiments, using the 2,200-volt circuit on intact animals, currents of 4 amp or more were passed through the animals many times for periods of from $^1/_2$ to 5 sec without causing ventricular fibrillation. In one case, however, in which the initial current was well in excess of 5 amp, the current fell gradually to zero during the 5-sec shock, resulting in ventricular fibrillation.

To show the difference between the high voltage and low voltage shocks, consider one experiment in which both types of shocks were applied to the same animal. A current of several amperes was passed through this animal twice for periods of from 2 to 5 sec without any permanent effect upon the heart or respiratory center. The animal recovered without the use of artificial respiration and, following each of these high voltage shocks, the pulse and breathing were normal. Then the animal was given a 2-sec shock from the 110-volt circuit, the current flowing equalling 0.1 amp. Following this shock, there was no evidence of peripheral pulse and, upon opening the thorax, the ventricles were observed to be in fibrillation. Another animal, exposed to 2 2,200-volt shocks and then allowed to recover from the anesthetic, showed no evidence of injury, and when visited 2 days later it was eating and playing with the other animals.

The evidence of these tests confirms the statements of the earlier investigators[1] and shows clearly that as far as the dog heart is concerned, the small current resulting from a low voltage shock is much more deadly than a current 50 times as large.

In the experiments reported in the foregoing, the heart lay directly in the path of the current, giving rise to the question as to how much of the current actually passed through that organ. Results of an earlier investigation[2] show that in a dog one-tenth of the total current passed through the heart when the current flowed from the head to the hind legs or from right fore leg to hind legs. On this basis, 0.01 amp was sufficient to cause ventricular fibrillation in the dog. To check this current value several experiments were made on animals with the chest open and the heart exposed. Electrodes used con-

Prepared especially for Electrical Engineering. *Not published in pamphlet form.*
1. See bibliography for all references.

sisted of 1-in. brass disks which were applied directly to opposite sides of the heart. In 5 animals tested, the average current required to upset the normal rhythmic activity of the heart and to throw the ventricles into fibrillation was found to be 0.0086 amp.

With larger values of current, using the same 1-in. electrodes, it was found that the currents of from 0.7 to 1 amp inhibited all activity in the heart muscle and did *not* result in fibrillation. Three different effects were observed: When the circuit was broken suddenly by opening the switch, the heart remained quiet for a few seconds and then resumed normal beating; when the current was reduced gradually from its high value, the heart would go into fibrillation at about 0.4 amp; and when the current was raised gradually from a low value more than 0.7 amp was required to bring the heart to rest.

Countershock Current

These experiments proved that currents from a few milliamperes to 0.4 amp flowing through the heart for several seconds would throw the ventricles into permanent fibrillation, whereas currents of 0.8 amp or more momentarily applied would stop fibrillation. Fibrillation also resulted when a large current flowed through the heart for 15 sec or more. In no case was a current of 0.45 amp or less sufficient to stop fibrillation. Although a period of 5 sec is not excessively long, a $^1/_2$ sec application of a heart current of 1 amp is just as effective as a longer application; in fact, effectiveness of the countershock seems to depend to a degree upon the brevity of its application. Experiments showed that a current larger than 0.8 amp was required to stop fibrillation when the current was increased gradually from a low value. For example, a current starting at 0.008 amp and gradually increased to 1 amp without opening the circuit failed to stop fibrillation when the circuit finally was interrupted. However, a few minutes later a countershock of 0.8 amp suddenly and momentari y applied to this same heart promptly stopped the fibrillation and the heart subsequently resumed its normal rhythmic activity. All these statements apply to a current path through the heart transverse with respect to the axis of that organ.

Application of Countershock to the Intact Animal

In experiments conducted to date, countershocks have been applied to intact animals by means of electrodes placed on either side of the thorax, the one on the left side directly over the heart and the one on the right somewhat lower down on the side of the animal. These positions of the electrodes provide a body circuit avoiding tissue that might be injured by the passage of electric current. Under these conditions and using electrodes having an area of 2.75 sq in., wrapped with a few layers of gauze soaked in saline solution and held in place by means of a rubber tube knotted around the body, fibrillating hearts have been recovered successfully with a total circuit current of 6 or 7 amp. This large current was required to insure that approximately 1 amp would flow through the heart, and its use required a circuit of from 200 to 300 volts.

Table I

Electrode Area, Sq In.	Total Applied Voltage, Volts	Total Current, Amperes	Total Contact Drop, Volts	Body Resistance, Ohms
2.75	124	0.8	105	29.0
2.75	150	3.0	110	35.0
2.75	194	4.8	110	18.0
2.75	215	5.7	78	20.5
			Avg. 101	Avg. 25.6
13.0	120	1.2	107	16.6
13.0	194	8.0	103	12.0
13.0	180	7.5	93	11.0
13.0	145	5.6	89	8.3
			Avg. 98	Avg. 12.0

A study of circuit conditions reveals a large contact drop at each electrode practically independent of the size of the electrode, a situation contrary to a simple ohms law relation. Experiments using electrodes of different sizes, one set having an area of 2.75 sq in., and the other having an area of 13 sq in., gave the results shown in Table I. The use of electrodes equipped with needle points to penetrate the skin, resulted in a lower contact voltage drop and reduced the circuit voltage required to send the desired current through the body.

Resuscitation Experiments With Countershock

Having established the limiting conditions already mentioned, attention was turned to the resuscitation of intact animals whose hearts had been left in fibrillation for varying periods of time. In these experiments the procedure was to place the animal under full morphia-ether anesthesia, fasten the electrodes to the body as previously described, and to induce ventricular fibrillation by administering a 110-volt a-c shock of a few seconds' duration. Subsequently, after varying intervals, the countershock was given with the same electrodes but with a voltage sufficient to send 6 or 7 amp through the animal The condition of the heart during these experiments was determined by means of an electrocardiograph.

In 19 out of 22 experiments the countershock brought the heart to rest, and in 16 of these 19 cases the heart resumed proper beating following the countershock.[3] It was found that if the heart were not left in fibrillation for more than 2 min the countershock alone was sufficient to resuscitate the animal and that the heart action that followed, although weak at first, rapidly increased in vigor and was sufficiently strong to reestablish blood circulation and result in permanent recovery.

In the tests, animals whose hearts had been left in fibrillation for periods up to 5 min were resuscitated successfully. However, in cases where the heart remained in fibrillation for more than 2 min spontaneous recovery of effective beats did not follow the countershock, although the countershock did stop fibrillation and enable the heart to resume a feeble beat. In these test cases stimulants were required

to strengthen the heart action and obtain permanent recovery. The most satisfactory stimulant[3] found was an injection of 2 cc of adrenalin of chloride 1:1,000 in the central end of the carotid artery, followed by an injection under a considerable pressure of a solution made up of calcium chloride ($CaCl_2$ 0.046 per cent) in a sodium chloride solution (NaCl 0.9 per cent) to which had been added a small amount of heparin. This latter solution, oxygenated and warmed to body temperature, was injected into the carotid artery where it passes through the neck, the amounts required varying from 4 to 10 cc per lb weight of the animal under test. This injection resulted in circulating a powerful cardiac stimulant in the coronaries and to fill the relaxed vascular bed so that when the ventricles did beat there was sufficient peripheral resistance to continue the coronary flow. Under these conditions, if the blood coming from the lungs is adequate for the needs of the heart, a continuation of heart action may be predicated.

Among the 16 initially successful resuscitations were 5 cases in which a strong and regular pulse developed following the countershock only to fade away gradually some 15 or 30 min later. For these partial successes no explanation is offered unless it be that the resistance of the organism was insufficient to counteract the consequences of the period of circulatory rest. If this explanation be correct it is possible that with more careful nursing and adequate stimuli the animals might have been carried over the period of depression.

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Communication by Carrier in Cable

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Considerable development work on carrier in cable has included an extensive installation on a 25-mile loop of underground cable. Sufficient pairs were provided in the cable and repeaters installed to set up 9 carrier telephone circuits 850 miles long. Tests showed transmission quality to be satisfactory, and adequate prevention of interference was secured. The obtaining of large numbers of carrier telephone circuits from cable was proved to be practicable.

A TRIAL installation recently was made in which, for the first time, carrier methods were applied to wires contained wholly in overland cable for the purpose of deriving a number of telephone circuits from each pair of wires. The trial centered at Morristown, N. J. A 25-mile length of underground cable was installed in the regular ducts on the New York-Chicago route in such a manner that both ends terminated in the long lines repeater station at Morristown. The cable contained 68 No. 16 AWG (1.3 mm diam) non-loaded pairs on which the carrier was applied. Sufficient repeaters and auxiliary equipment were provided at Morristown so that these 68 pairs could be connected together with repeaters at 25-mile intervals to form the equivalent of an 850-mile 4-wire circuit.

From this 850-mile 4-wire circuit 9 carrier telephone circuits were derived, using frequencies between 4 and 40 kc. The diagram of Fig. 1 shows the system simulated by the experimental set-up.

In a practical installation the one-way paths would be shielded from each other either by placing them in separate cables or by placing them in a single cable divided into 2 electrical compartments by means of a specially arranged shield. In the set-up at Morristown the circuit was necessarily arranged somewhat differently since only one cable was available. Transmission over all loops in this cable went in the same direction, half the loops then being connected in tandem to simulate one direction of transmission through a long circuit and the other half in

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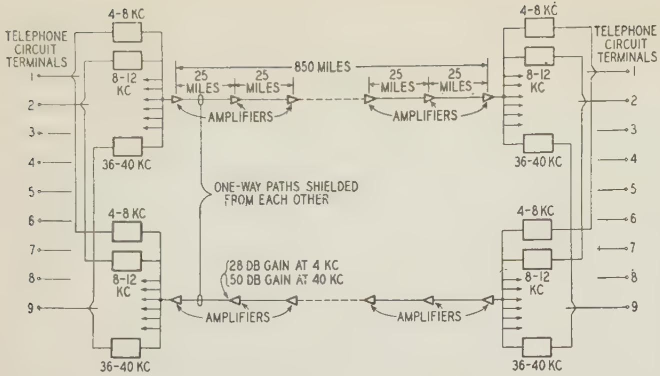


Fig. 1. Schematic diagram of cable carrier system

tandem to simulate the other direction of transmission.

It will be noted that in the cable system of Fig. 1 the practical equivalent of 2 electrical paths was provided, one for transmission in each direction, the same range of frequencies being used in each direction. This differed from common open-wire practice in which the frequency range is split in 2 and used, one half for transmission in one direction, the other half for transmission in the other. The frequency allocation of the Morristown cable carrier system is compared in Fig. 2 with existing open-wire systems in this country. Except for this matter of difference in frequency allocation, the fundamental carrier methods used in this cable system did not differ in principle from those already used on open wires. As will be noted in Fig. 2 all of these carrier telephone systems use the single sideband method of transmission with the carrier suppressed.

A schematic diagram of the terminal apparatus used in deriving one of the telephone circuits is shown in Fig. 3. Its general resemblance to the terminal apparatus used in present open-wire systems is evident so no further discussion of this seems required. Five relay rack bays carrying terminal equipment (exclusive of line amplifiers) for one system terminal yielding 9 telephone circuits are shown in Fig. 4.

Important problems in cable carrier transmission are:

1. Keeping circuits electrically separated from each other, i. e., preventing troublesome crosstalk.
2. Maintaining stability of transmission.

Crosstalk

With respect to crosstalk, the first and most important requirement is to secure a very high degree of electrical separation between paths transmitting in opposite directions. Careful crosstalk tests demonstrated that by placing east going circuits in one cable and west going circuits in another, the necessary degree of separation could be obtained even though the 2 cables were carried in adjacent ducts. Tests on short cable lengths indicate that adequate separation can probably be secured by means of a properly designed shield; one practical form of such a shield consists of alternate layers of copper and iron tapes. With such a shield a cable may be divided into 2 compartments and thus carry both directions of transmission.

Having thus separated opposite bound transmissions there is left the problem of keeping the crosstalk between same direction transmissions within proper bounds. In the cable used for the Morristown trial the 16 AWG pairs used for the carrier were separated from each other by sandwiching them in between No. 19 AWG (0.9 mm diam) quads of the usual construction. These quads served as partial shields between the carrier circuits and would in a commercial installation have been suitable for regular voice frequency use. Thus a considerable reduction in the crosstalk between the carrier pairs was effected.

When the problem of keeping crosstalk between circuits transmitting in the same direction within proper bounds is examined it becomes evident that no matter how high the line amplifier gains may be, these gains do not augment this crosstalk since if all of the circuits are alike transmission remains at the same level on all circuits. Not so evident perhaps is another fact that crosstalk currents due to unbalances at different points tend to arrive at the distant end of the disturbed circuit at the same time. This makes it possible to neutralize a good part of the crosstalk over a wide range of frequency by introducing compensating unbalances at only a comparatively few points. In practice, balancing at only one point in a repeater section (which may be an intermediate point or either extremity) serves to make possible considerable reduction of the crosstalk. In the Morristown set-up balancing arrangements were

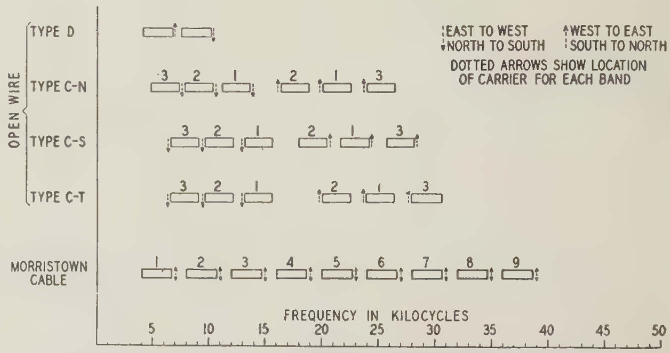


Fig. 2. Frequency allocations of carrier telephone systems

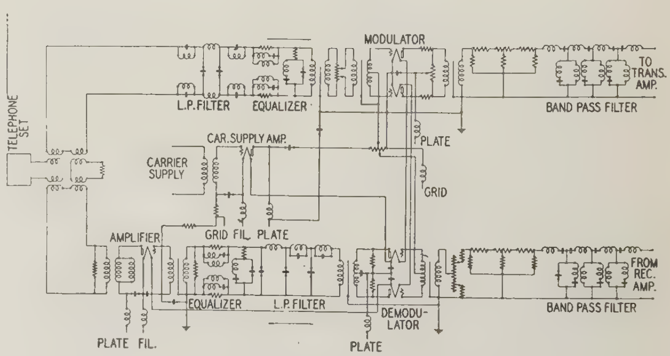


Fig. 3. Terminal of one telephone circuit

applied at an intermediate point in the cable and found to be entirely adequate for the frequency range involved, in fact transmission of considerably higher frequencies would have been possible without undue crosstalk. Other tests have indicated that, thanks to these balancing means, the 19-gage quads used in the Morristown cable for separating the 16-gage pairs from each other can probably be dispensed with, even for frequencies considerably above those used in the trial.

The experimental panel on which the circuits were brought together for balancing was installed in a weather-proof hut near the center of the 25-mile repeater section. By this means all pair to pair combinations in the group to be balanced were brought into proximity so that the leads to the balancing devices could be kept short. The actual balancing was accomplished by either or both of 2 methods: (1) connecting small condensers made up of twisted pairs, between wires of different cable circuits; (2) coupling wires of different circuits together through small air-core transformers. Each unit was individually adjusted after measurement of the crosstalk between the various combinations.

Maintaining Stability of Transmission

Referring to the problem of stability, the importance of this will be appreciated from the fact that the average attenuation at the carrier frequencies employed in the 850-mile circuit as set up at Morristown was about 1,300 db. A circuit was actually set up and tested consisting of 9 of the carrier links in tandem, giving 7,650 miles of 2-way telephone circuit whose total attenuation without amplifiers was about 12,000 db. This attenuation, on an energy basis, amounts to $10^{1,200}$. This ratio, representing the amplification necessary, quite transcends ratios such as the size of the total universe to the size of the smallest known particle of matter.

Balancing this huge amplification against the correspondingly huge loss, to the required precision, 1 or 2 db, is a difficult problem. Fortunately, a new form of amplifier employing the principle of negative feedback has been invented by H. S. Black of Bell Telephone Laboratories and may be described later in an Institute paper. By making use of this negative feedback principle, amplifiers were produced for this job giving an amplification of 50–60 db and this amplification did not change more than 0.01 db with normal battery and tube variations. This is ample stability even when it is considered that, with amplifiers spaced 25 miles apart, there would be 160 of these in tandem on a circuit 4,000 miles long.

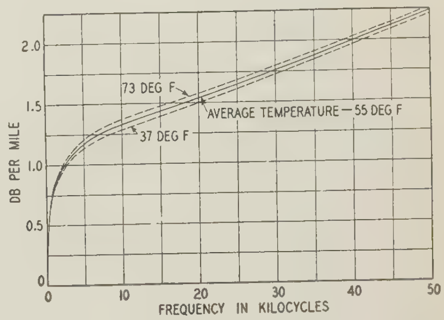


Fig. 5. Transmission loss of 16-gage cable pair

As is well known, the losses introduced by cable circuits do not remain constant even though the circuits are kept dry by means of the air-tight lead cable sheaths. Variation in temperature is principally responsible for the variation in efficiency of the circuits. The change in temperature, of course, alters the resistance of the wires and to a lesser extent changes the other primary constants, particularly the dielectric conductance. In Fig. 5 is shown the transmission loss plotted against frequency of a 25-mile length of 16-gage cable pair at average temperature (taken as 55 deg F) and also the effect of changing this temperature ± 18 deg F which is about the variation experienced in underground cable in this section of the country. For a circuit 1,000 miles long the yearly variation amounts to about 100 db.

The transmission loss at any frequency is a simple function of the d-c resistance. Consequently, measurement of the d-c resistance of a pilot wire circuit exposed to the same temperature variations can be used to control gains and equalizer adjustments to overcome the effect of this temperature variation. In Fig. 6 is shown a schematic diagram of the pilot wire transmission regulation system used in the Morristown experiments, while the photograph of Fig. 7 indicates the appearance of the apparatus. This pilot wire regulation system takes care of a 25-mile length of cable. The arrangement of the regulating networks is such that variation of a single resistance causes the transmission loss to be varied a different amount at different frequencies as re-

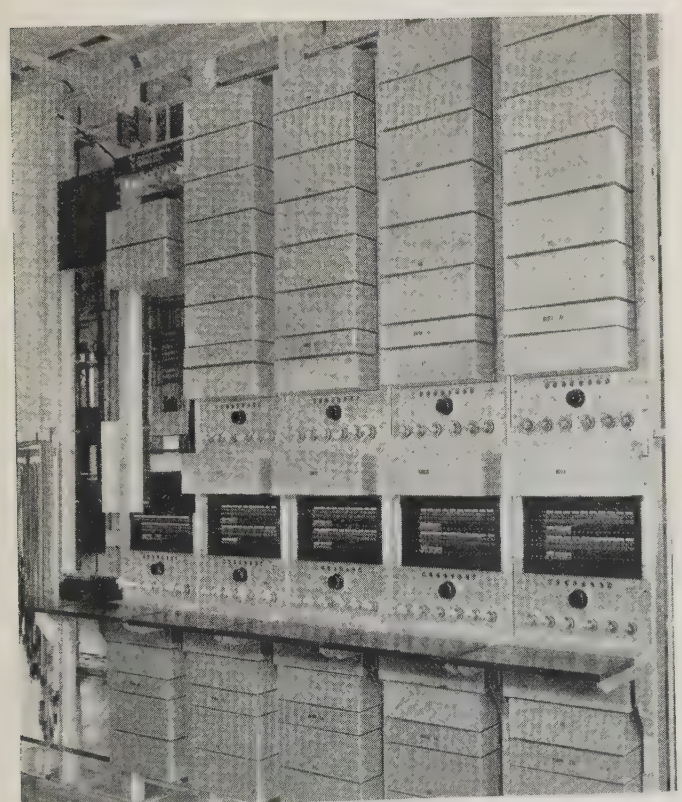


Fig. 4. Terminal equipment for 9 telephone circuits

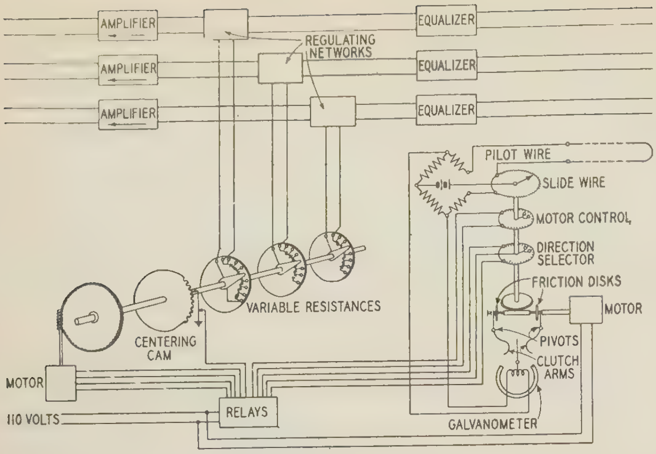


Fig. 6. Automatic transmission regulating system

quired by the variation in the line loss shown in Fig. 5. In Fig. 6 the relay system is omitted for the sake of simplicity. The function of the relay system is, of course, to control the rotation of the shaft carrying the variable resistances so that it follows the rotation of the shaft associated with the master mechanism. The centering cam is provided to avoid "hunting."

The Morristown experiments have shown that this form of regulation is adequate when underground cables are employed. Similar regulation of aerial cables in which the transmission variation with time is 3 times as large and several hundred times as rapid presents greater but not insuperable difficulties.

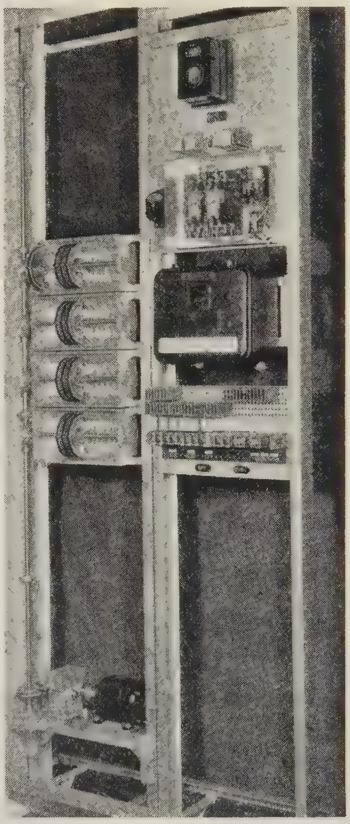
Obtaining High Amplifications

The attenuation of cable pairs being inherently high at carrier frequencies, high amplifier gains are called for, otherwise the cost of the carrier circuits goes up very materially. Since as the power carrying capacity of the repeaters is increased a point is soon reached where it becomes very expensive to go further, high amplifications must be secured by letting the transmitted currents become very weak before amplifying them. A natural limit to this is found in the so-called thermal or resistance noise generated by all conductors. (See "Thermal Agitation of Electricity in Conductors," by J. B. Johnson, *Phys. Rev.*, v. 32, 1928, p. 97–109, and "Thermal Agitation of Electric Charge in Conductors," by H. Nyquist, *Phys. Rev.*, v. 32, 1928, p. 110–3.) Similar natural and largely insuperable noises are introduced by the vacuum tubes in the amplifiers. Other sources of noise are: (1) telegraph and signaling circuits worked on other pairs in the same cable with the carrier circuits; (2) radio stations; (3) noise from power systems, particularly electric railways. The latter 2 disturbances originate outside the cable so that they are subject to the shielding effect of the lead sheath which increases rapidly with increasing frequency. Generally speaking, in a new cable both of these and also the noises from other circuits in the same cable may be relegated by location and design to comparatively minor importance. On existing cables, however, they may require special treatment. In all cases, however, the lower levels at the upper frequencies, which largely determine the repeater spacings, are established primarily by the thermal noise in the conductors and by the corresponding noises in the vacuum tubes. In the Morristown installation the amplifications were kept small enough and the levels high enough so that noise was not an important factor.

Experimental Results

A large number and wide variety of tests have been made using the set-up at Morristown. These were generally of too technical a character to be of interest

Variable resistances for control of 12 individual lines



Master control mechanism

Motor geared to shaft

Fig. 7. Automatic transmission regulating equipment, covers removed

in a general paper such as this one. It will be of chief interest to note that no serious difficulty was experienced in setting up the 850-mile 4-wire 4 to 40-kc circuit with the necessary constancy of transmission loss at different frequencies, although the equalizer arrangements which made this possible presented intricate and difficult problems of design. Nine separate carrier telephone conversations were transmitted over this broad band circuit without difficulty due to cross-modulation.

Each carrier telephone circuit was designed to yield a frequency band at least 2,500 cycles wide, extending from about 250 cycles to somewhat above 2,750 cycles when 5 such carrier links are connected in tandem. This liberal frequency band and the very satisfactory linearity of transmission

over the entire system, gave a very excellent quality of transmission. In order to exaggerate any quality impairment which might have been present the 9 carrier circuits were, as noted previously, connected for test in tandem giving a total length of about 7,650 miles of 2-way telephone circuit. The quality of transmission over this circuit also was found very satisfactory. In fact, the quality was not greatly impaired even when twice this length of one-way circuit was established by connecting all the lengths in tandem, giving a 15,300-mile circuit whose overall loss without amplifiers was about 24,000 db.

As noted previously, the fact that the cable pairs were left non-loaded gives the cable carrier circuits the advantage of very high transmission velocity. Including the effect of the apparatus this velocity is approximately 100,000 miles per sec; 5 or 6 times as great as the highest velocity loaded voice-frequency toll cable circuits now employed in the United States. This velocity is ample for telephoning satisfactorily over any distances possible on this earth.

Conclusion

Under the present economic conditions there is no immediate demand for the installation of systems of this type. Consequently development work is being pursued further before preparing a system for commercial use. The final embodiment or embodiments of the cable carrier system will probably differ widely, therefore, from the system described in this paper. Since the transmission performance of the experimental system was so completely satisfactory, emphasis is now being directed toward producing more economical systems which will be applicable to shorter circuits. Preliminary indications from this work are that some form of cable carrier system will ultimately find important application on circuits measured in tens rather than hundreds of miles.

Burlington Generating Station Improvements

The installation of a new boiler and high-back-pressure non-condensing turbine which exhausts into 3 older turbines, reduced the fuel consumption at the Burlington station from 22,000–25,000 Btu per kwhr to about 15,000 Btu per kwhr. Electrical and mechanical details in the improvement of the station are described in this article.

By
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W. P. GAVIT — United Engrs. and Constructors, Inc., Philadelphia, Pa.

THE recent development at Burlington generating station of Public Service Electric and Gas Company of New Jersey is of special interest in these days of stringent economies and efforts to make existing equipment go as far as possible. The station contained 3 12,500-kw turbine-generators from 10 to 16 years old with a stoker fired boiler plant all operating at 200 lb steam pressure with 150 deg superheat. The fuel consumption was 22,000 to 25,000 Btu per kwhr which is about what would be expected with these steam conditions and equipment of that period.

The installation of a high pressure pulverized fuel fired boiler and an 18,000-kw high back pressure non-condensing turbine reduced the station heat rate to about 15,000 Btu per kwhr. As a consequence of this improved economy the Burlington generating station is now prime base load capacity and may be expected to continue in this classification for some years to come.

An unfortunate accident that occurred in January 1933 damaged the turbine beyond repair and until the new turbine is completed the old units are being supplied with steam through a reducing valve from the new boiler.

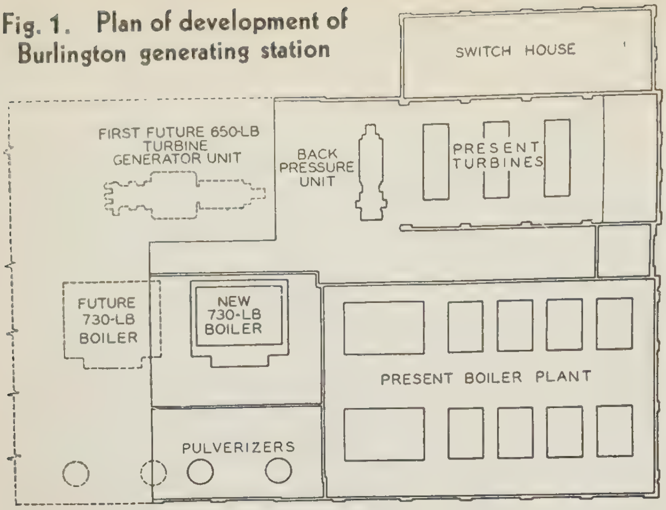
Plans for Development of Station

The general development of the generation and distribution systems of Public Service Electric and Gas Company will require the location of additional generating capacity in the district served by Burlington generating station and tentative plans were formulated for the extension of this plant. The first step of the extension was to consist of 2 high pressure 75,000-kw turbine-generators with 4 boilers of such a capacity that 3 could produce sufficient steam to operate the 2 turbines.

The load conditions existing at the time these plans were formulated indicated that the extension would not be necessary until some time later. However a capacity contract for the supply of energy from a source outside the Public Service system was to expire at the end of 1931 and the provision of efficient capacity in the Burlington station was de-

Full text of "Improvements at Burlington Generating Station" (No. 33-76) presented at the A.I.E.E. summer convention, Chicago, Ill., June 26–30, 1933.

Fig. 1. Plan of development of Burlington generating station



sirable as it would obviate the necessity of renewing this contract.

Studies indicated that the efficiency of the Burlington station as a whole could be raised to a satisfactory value by superimposing a high pressure turbine-generator upon the existing 200-lb system. Sufficient steam for the operation of the station with such a high pressure unit could be supplied by one high pressure boiler of the size and type contemplated for the future extension. If this installation were made the old turbine-generators would remain an economical part of the station after the proposed future extension was completed as they could be operated whenever the excess or spare boiler capacity was available. With modern steam generating equipment the time out for maintenance is small so that this excess boiler capacity would normally be available most of the time.

With these several factors in mind it was decided to install one 30,300-sq ft boiler designed for operation with a drum pressure of 730 lb per sq in. gage and a total steam temperature of 850 deg F. A pressure higher than 730 lb per sq in. was not adopted for 2 main reasons. It was desired to avoid the added equipment and operating complications of a reheat cycle. Also 730 lb was the maximum for riveted construction without going to special or expensive design as welded drum construction had not been approved by the code of the American Society of Mechanical Engineers at the time the boilers were under consideration.

Along with this boiler a turbine-generator was installed of 18,000-kw capacity designed for a throttle pressure of 650 lb per sq in. and a total steam temperature of 875 deg F. The turbine was designed to exhaust at a maximum pressure of 205 lb per sq in. into a header system from which the old turbines are supplied. The boiler is capable of producing and the turbine can pass sufficient steam to operate the 3 old turbines at full load. A plan of the present and proposed Burlington station is shown in Fig. 1.

This program provided 18,000 kw of new capacity and brought the old turbines into efficient use without the expense of any boiler capacity in excess of that which would be required for the future 2-unit extension.

Heat Balance Arrangement

A heat balance arrangement was devised which took the fullest practical advantage of the possibilities of the existing equipment. A diagram of the operating heat balance is shown in Fig. 2. The proposed arrangement included a 3-stage regenerative feed heating system and an evaporator for make-up. The low pressure heater is supplied with steam bled from the 2 newest of the old turbines. The pressure at the lower bleed point of the oldest of the 3 original units does not correspond to that of the other 2 because of a difference in design. It therefore was not practical to interconnect the lower bleed points of all 3 units.

The intermediate and deaerating heaters are supplied with steam bled into a common header from the upper bleed point of all 3 old turbines. The high pressure heater receives its steam from the exhaust of the high pressure unit. The lower bleed point on the old machine was used to extract steam for a make-up evaporator.

For the loads at which the station was expected to operate, a heat rate of about 15,000 Btu per kwhr delivered to the outgoing lines was expected. This represents an improvement over the old station of 32 to 40 per cent. An additional saving in operating labor and maintenance costs was expected as a result of shutting down the old boiler plant. The results attained in actual operation fully bear out predictions as to performance.

Boiler, Furnace, and Superheater

A crossdrum straight tube type boiler was chosen as offering the least expensive design for the pressure decided upon. To have adopted the bent tube type would have meant very special design or (at that time) the use of forged drums. A high boiler with air preheater was used as giving greater simplicity and fewer kinds of equipment than a low boiler with

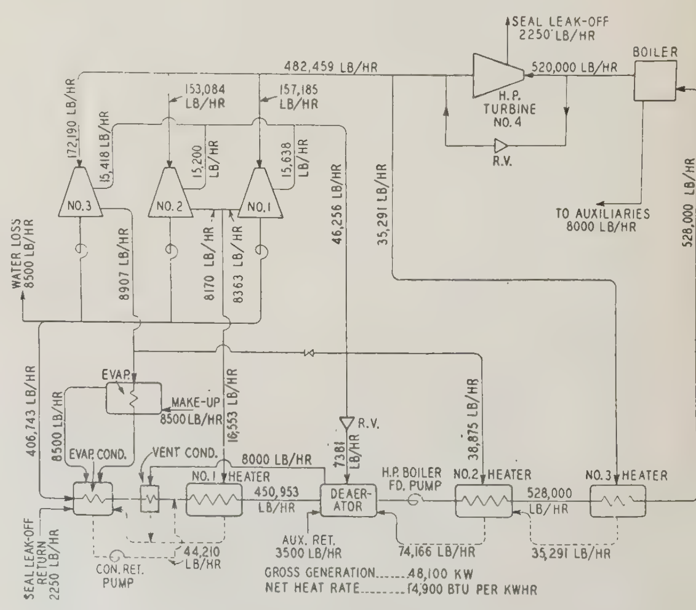


Fig. 2. Heat balance flow diagram of Burlington generating station

economizer and air heater. An overall boiler efficiency of about 85 per cent was used as basis of design.

The furnace has water walls on the 2 sides and rear and on the part of the front wall above the burners. The whole unit is steel encased and insulated with the casing so placed that all water wall and bottom screen downcomers and connections from drum to superheater headers are within the casing. This arrangement avoids the necessity of insulating all these pipes, improves the appearance of the unit as a whole, and makes it cleaner owing to the absence of a multiplicity of external pipes to collect dust.

The superheater is of the multi-loop bare tube type and contains approximately 9,200 sq ft of effective surface. Various types of superheater were considered in selecting this design and arrangement. A straight parallel flow design would not give the desired final steam temperature. A combination part parallel and part counter current design would give a satisfactory superheat curve but was expensive and complicated in design. A straight counter current design was finally selected as combining economy of cost, simplicity of design, and satisfactory performance characteristics.

Each superheater element consists of $6^1/_2$ return bends, the upper $5^1/_2$ of which are of ordinary mild steel, and the lower of chrome vanadium steel. It might have been desirable to make a greater proportion of the tubes of alloy steel, but the maximum one piece length of alloy tubing obtainable was only sufficient for one loop. No satisfactory method for welding 2 pieces of alloy steel was known, though it could satisfactorily be welded to the ordinary steel. Recently the alloy steel has been made in longer pieces and replacement elements have a loop and a half of this material. However, nothing has occurred in operation that would indicate that the additional length of alloy steel was essential.

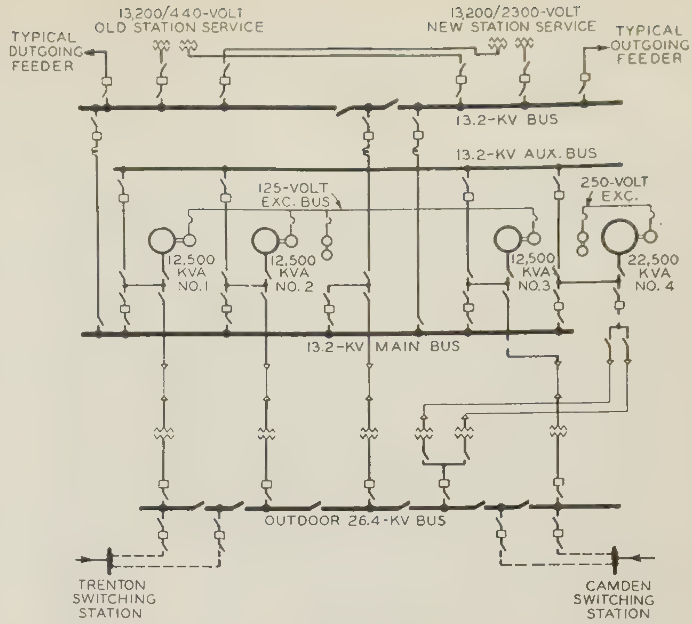


Fig. 4. Single line diagram of electrical connections

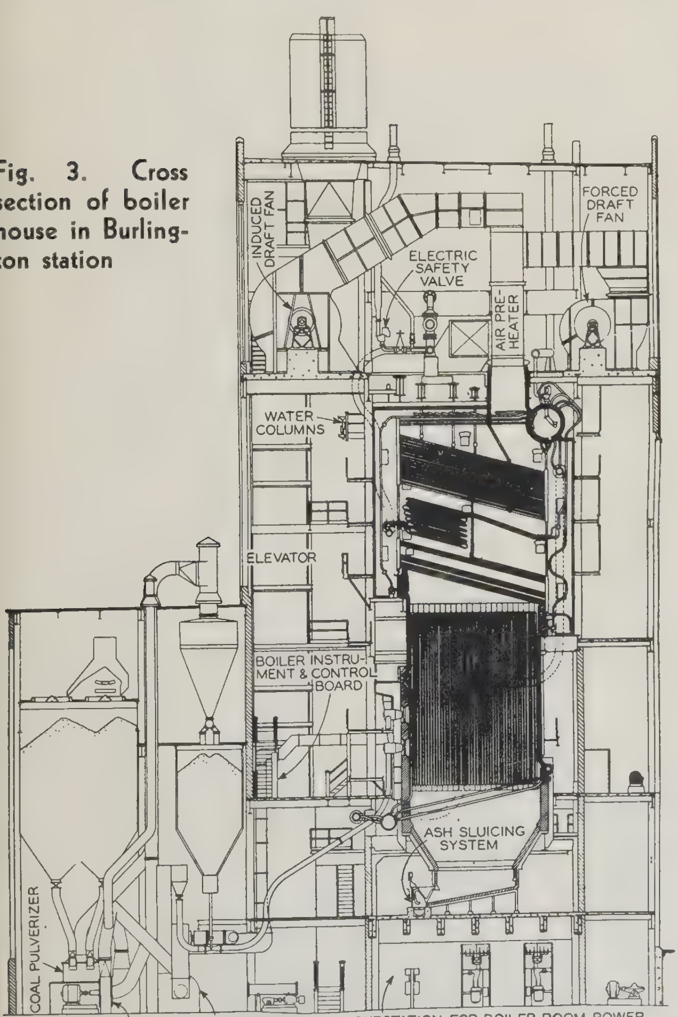


Fig. 3. Cross section of boiler house in Burlington station

Pulverized Fuel System

Pulverized fuel firing was selected partly because the designers felt that units of such size are more suited to pulverized fuel firing than to stokers and partly because of the flexibility of the pulverized fuel furnace in the matter of burning fuels of widely varying characteristics.

The design of the pulverized fuel system combines as far as possible the advantages of the storage system with its close control and greater flexibility with the compactness and straightforwardness of the direct system. Bins and feeders are interposed between the mills and burners to assure continuity of rating on the boiler during temporary stoppage of the pulverizing equipment. As will be noted from inspection of the boiler room cross section, Fig. 3, the raw coal bunker, mills, primary air fans, separators, pulverized fuel bin and feeders are compactly arranged in a low section of the building. The burner pipes extend from the feeders up to 8 30-in. horizontal burners. This arrangement assures a maximum of light and air to the boiler firing aisle.

The combustion control system is of the air actuated type and varies the rate of coal and air supply and draft in accordance with changes of pressure in the main steam header.

The forced and induced draft fans are motor

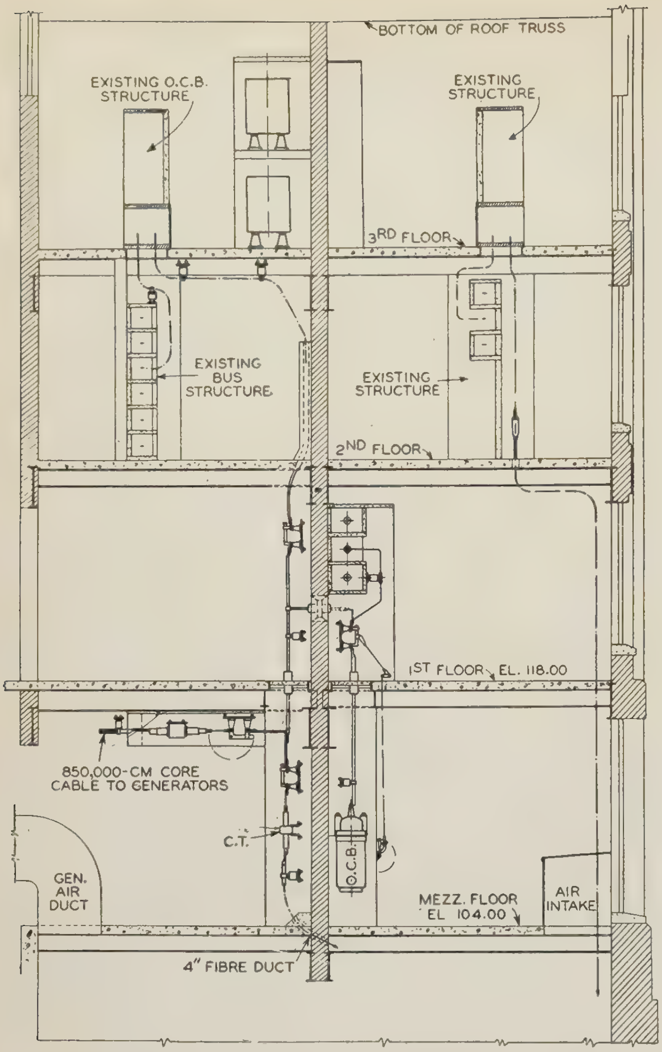


Fig. 5. Physical arrangement of indoor bus structure

driven. Each fan is provided with 2 constant speed induction motors, one at each end of the fan shaft. One of the motors is of size and speed suitable for operation of the fan at maximum load while the other smaller motor is of size and speed suitable for operation up to about $^2/_3$ maximum load. The fans run at constant speed, and regulation of the quantity of air or gas delivered at either high or low speed is by manipulation of the inlet vanes on the fans.

In selecting this drive system, 5 arrangements were considered:

1. Two constant speed motors with vane control.
2. Two constant speed motors with damper control.
3. One 2-winding constant speed motor with vane control.
4. One 2-winding constant speed motor with damper control.
5. Two variable speed motors.

The arrangement with 2 constant speed motors and vane control was found to be the most economical. This system is also relatively simple and provides 2 motors, either one of which may be operated in case of trouble with the other.

The forced draft fans deliver air through a plate type air preheater to the burners, mills, and feeders. At 525,000 lb per hr actual evaporation the air is preheated to a temperature of 498 deg F and the flue gas temperature is thereby reduced to 456 deg F.

Steam Connections

The high pressure turbine is a single-cylinder noncondensing straight-reaction unit designed for a throttle pressure of 650 lb per sq in. gage and a total steam temperature up to 875 deg F. In view of the fact that only one high pressure steam generating unit was to be installed it was necessary to design the steam system so that the 3 existing turbines could be operated on the old boilers in case the high pressure boiler should be out of service. Some consideration was given a scheme of carrying a constant back pressure on the new high pressure turbine so that no changes would have to be made to the old low pressure units. This was discarded in favor of a varying back pressure because of better overall economy. The only change to the 3 old turbines was the substitution of new nozzles for the inlet steam and increased clearances.

Under normal operation the high pressure unit and the 3 low pressure units run as a compound turbine, control being entirely by the high pressure turbine governor. The generators of the 4 elements are tied together electrically and the governors on the 3 low pressure units are wide open. With this arrangement the exhaust pressure from the high pressure unit and consequently the inlet pressure to low pressure machines varies with the load.

The auxiliaries in the old station were mainly steam driven and the question arose as to the economical disposition of the exhaust from these auxiliaries with the regenerative cycle proposed for the new installation. Studies made to determine the economic value of substituting motor drives for the existing steam drives indicated a fuel saving sufficient to make such a change profitable and most of the station auxiliaries, therefore, were motorized.

The governing system and valve arrangements are such that anything but an extraordinary disturbance of the system is taken care of automatically. If one of the generators should be disconnected from the load all the steam from the high pressure unit would tend to pass through the remaining 2 low pressure turbines. These 2 generators would as a consequence advance in phase and momentarily take an overload. At the same time the pressure at the high pressure turbine exhaust would rise sharply. This unit is provided with a device to limit the exhaust pressure to 205 lb. The rise in exhaust pressure would cause this device to function and reduce the flow of steam to the high pressure unit, thus restoring the system to equilibrium.

A by-pass with automatic reducing valve and desuperheater is provided between the high and low pressure steam headers. If the high pressure unit should trip out, steam automatically would be passed to the low pressure header through this by-pass and operation of the low pressure unit would not be disturbed. This also permits the old units to be operated on steam from the new boiler during periods when the high pressure turbine is out of service, thus

allowing advantage to be taken of the higher efficiency of the new boiler.

ELECTRICAL CONNECTIONS

The station is connected to the Public Service Electric and Gas Company's transmission system at both Camden and Trenton, as indicated on the diagram of Fig. 4. It also is connected at both these points to the Philadelphia Electric Company's system.

The addition of 22,500 kva to the station capacity and the changes made in circuits connecting the station to the Public Service system, brought about a condition for which the rupturing capacity of all main circuit breakers was inadequate. In order to avoid complete replacement of these circuit breakers with building changes which would be difficult to make, steps were taken to increase the rupturing capacity of the existing equipment. This increase was accomplished by changing the system of connections, introducing reactors, and making certain changes to the breakers themselves.

With these changes, it was necessary to purchase new breakers only for connections to the new main or synchronizing bus. These circuit breakers are of 1,000,000-kva rupturing capacity. All 26,000-volt breakers were equipped with deion grids which appreciably increase their rupturing capacity. The physical arrangement of the indoor switching equipment with the new breakers and new bus on the first 2 floors is shown in Fig. 5.

With the new system of connections, each generator is connected to the 26,000-volt bus through its own transformer or group of transformers, but, in addition, the generators are paralleled on the 13,000-volt side through the synchronizing bus, and normally remain connected to it. This arrangement permits the 26,000-volt bus to be sectionalized as desired. Normally the Camden section of the system is connected to one bus section and the Trenton to the other. This ties the 2 sections together through 2 transformer groups in series, permitting the shifting of transformers between the Trenton and Camden bus sections as desired. The outdoor switching station is shown in Fig. 6.

The station auxiliaries are supplied from a 13,200-volt auxiliary bus. This bus is fed through 2 connections to the main or synchronizing bus and one connection to the 26,000-volt outdoor bus. This permits operation of the auxiliary bus from the 26,000-volt system even though the turbines in the station should be shut down, and allows sectionalizing of the auxiliary bus as desired. The spare transformer between the main and 26,000-volt buses also may be used for the auxiliary bus supply, thus avoiding the necessity of a separate transformer for auxiliary supply from the 26,000-volt system.

Two station service feeders are provided, one for the auxiliaries in the old station provided with a 13,200/440-volt transformer bank and the other for the new boiler plant substation provided with a 13,200/2,300-volt transformer bank. The substation for the supply of power to the new boiler plant is located beneath the latter and is designed to provide for extension to take care of additions as they are made. This location is close to the load center and permits a simple and direct arrangement of feeders to the various motors.

Excitation of the old units was by separate turbine-driven 125-volt generators. The elimination of steam auxiliaries previously discussed included these exciters and they were replaced with new shaft-end generators on the main generators. An emergency exciter bus is energized from a motor driven generator. The new unit is provided with a 250-volt shaft-end exciter and a motor-driven emergency exciter which will be connected to the emergency exciter bus of the future extensions.

WELDED PIPE JOINTS USED

One of the interesting features of this installation is the fact that, as far as was practical, pipe joints were welded. Flanged joints were used only for connections to large valves and where joints must be broken frequently.

This is the first high pressure power plant in which welding for pipe joints was used throughout to such a large extent. As many welded sections as possible were made in the fabricator's shop, by the electric arc weld process using coated rod. The extent to which shop welding could be used was of course limited by the size of pipe sections that could be shipped to the job. Field welds were made by the oxyacetylene process and all high pressure pipe welds were locally annealed after completion. The valves in the larger lines were flanged but many smaller valves were welded directly to the pipe.

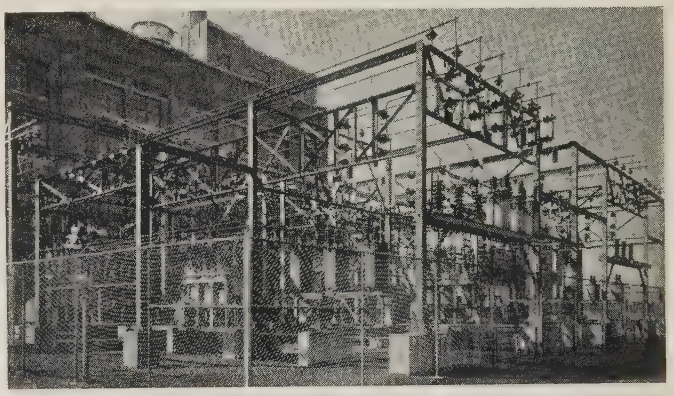


Fig. 6. Outdoor switching station at Burlington generating station

The annealing of the large pipe welds presented a problem for which no equipment was available. A portable box was made up of steel plate lined with asbestos which could be placed over the joint. With the box in place the joint was heated to the desired temperature with oil torches after which the box was packed tight with asbestos and the pipe permitted to cool. All field welds were tested after completion by applying hydrostatic pressure of 1,500 lb per sq in., and hammering with a heavy sledge. No failure of welds has been experienced to date.

Shortly after the new installation was put in service the price of fuel oil receded to a low level. Studies indicated that its use in place of coal would result in a material saving in operating cost even after deducting fixed charges which included a high amortization on the installation cost of the necessary oil equipment.

A fuel oil storage, handling, and burning system was installed comprising a 20,000-bbl tank, an unloading wharf at the river, and the necessary pumping, heating, and burning equipment. Oil burners are inserted through the center of the pulverized coal burners and their installation required practically no changes in the original equipment. A change from oil to coal or vice versa may be made in a few minutes and without interruption to boiler operation.

Operation

The boiler and turbine were put in service February 17, 1932. Outages due to boiler trouble up to December 24, 1932, totaled 917 hr representing total availability for the boiler of about 88 per cent. Outages due to turbine trouble some of which were coincident with boiler outages totaled, up to December 15, 1932, about 1281 hr, giving a total availability of about 82 per cent. None of the outages can definitely be attributed to the pressure and temperature or to the system. They were for the most part of the character usually encountered during the early operating period of new equipment.

Of the 10 turbine outages 5 were for inspection or adjustment, 3 were for changes to bearings, 1 was to determine the cause of a trip-out and 1 was to increase shroud clearance. On December 15th the turbine was shut down to permit installing new end tightening on the shroud bands and a new design of high pressure dummy packing. At the same time some changes were made in the admission valve flanges and bolting to improve the expansion stress distribution.

The turbine was returned to service early in January, 1933, but a few days later was wrecked due to some internal failure the exact nature of which has not been determined. The vibration accompanying the turbine trouble caused the breakage of one of the oil lines to the valve operating gear on top of the turbine. The leaking oil caught fire resulting in a quite serious but localized conflagration. The resulting damage was confined to the turbine and objects near by. Neither the generator of the new unit nor any of the other units in the station was damaged other than by smoke. The station is now operating on steam from the new boiler through a reducing valve and desuperheater.

Operation of the plant aside from the accident to the turbine has been satisfactory. There has been some corrosion in the superheater tubes, and a few superheater tube leaks have occurred due to incomplete welding of return bends.

The turbine was opened up for inspection early in August, 1932, and a heavy gray deposit was found on the blades from the 12th row down to the exhaust, increasing in quantity toward the exhaust end with the last 2 rows comparatively free. This deposit, of course, is carried over from the boiler and through the superheater and consists of the materials used for treatment of the boiler feed water. Elimination of this fouling on turbine blading is one of the problems that must be solved in connection with high pressure and temperature installations. At Burlington the deposited material is very soluble and easily removed by washing with water. However, the turbine must be cooled down considerably before water can be introduced and considerable operating time must be sacrificed.

The station has carried a maximum load of about 53,000 kw with a total steam generation of 625,000 lb per hr, and when fouling of the turbine can be overcome a load at or near this value can be carried continuously with oil fuel. With coal firing the maximum load carried was 51,500 kw with a total steam generation of 550,000 lb per hr. The higher water rate with oil firing is due to a combination of the following circumstances: (1) higher temperature circulating water at the time the above record was made; (2) fouling of turbine blades as previously described herein; (3) some steam leakages that developed within the turbine. The boiler operated continuously from August 13 to December 24, 1932, and during this period produced 1,373 million lb of steam. This is an average of about 429,000 lb per hr.

X Rays—

an Elementary Discussion

A POPULAR discussion of X rays which may serve to clarify some of the fundamentals of this subject to those readers of Electrical Engineering not too familiar with these and other highly penetrating waves, was presented recently by Dr. W. D. Coolidge (A'10) director of the research laboratory of the General Electric Company, Schenectady, N. Y. Doctor Coolidge's talk follows:

Thirty-three years ago the world was startled by the announcement of the discovery of a new kind of radiation, capable of penetrating substances opaque to ordinary light. This new radiation had been discovered by Professor William Conrad Roentgen, of the University of Wurzburg in Germany, and had been produced by passing a high voltage electric discharge through a Crookes tube—an evacuated glass bulb with 2 metal electrodes. The new radiation also was capable of affecting a photographic plate, or imparting electrical conductivity to gases, and of causing certain materials to become luminous in the dark.

Full text of a talk delivered at a colloquium at the General Electric Research Laboratory, Schenectady, N. Y., April 21, 1933. *Not published in pamphlet form.*

In spite of a tremendous amount of effort on the part of the physicists of the world to unravel the mystery, the nature of this new radiation remained unknown for the following 17 years. It was then fitting that it should be designated by the letter X, the symbol so often used in algebra for the unknown quantity.

Regardless of the nature of these new radiations, their tremendous importance in the field of medical diagnosis was established with the publication of that first shadow picture of a human hand made by Roentgen. A weaker man might well have been lured from the paths of pure science to seek popular acclaim and financial gain from the application of these new radiations to human needs. But not Roentgen. Professor Drude, with whom I studied in Leipzig, from 1898 to 1900 and who was well acquainted with Roentgen, told me that the latter had always regretted having allowed his X ray picture of a hand to be published, as it gave a popular rather than a purely scientific aspect to his work.

Through the efforts of many investigators, the art of producing X rays has developed very rapidly. Radical changes have been made in both the X ray tube and the high voltage generator. From a relatively feeble and very uncertain source of radiation, the X ray generator has come to be as dependable and as easy to operate as the ordinary incandescent lamp, and any desired intensity of X radiation and any desired penetrating power can now be produced.

The general method used is the same today as that first employed by Roentgen. In a vacuum, tiny particles of negative electricity—electrons—are brought, by the use of high voltage, to enormous velocities—thousands of miles per second—and are then suddenly stopped by collision with a solid body, the so-called target, interposed in their path.

X rays radiate in all directions from the spot on the target where the collisions take place. They are due to the mutual interaction of the rapidly moving electrons on the one hand, and the electrons and positively charged nuclei, constituting the atoms of the target, on the other hand.

While this is the only method which we have on earth for producing X rays, what we now know of their nature tells us that, like ordinary light, they would be emitted from any body raised to a sufficiently high temperature. A metal wire raised to a temperature of say 1,000 deg F gives off red light. As its temperature is increased, light of other colors, orange, yellow, green, blue, and violet, is progressively added to the red. At the temperature of the tungsten filament in the modern incandescent lamp, some 4,500 deg F., the light is still quite yellow compared with sunlight, but if this tungsten filament, which, unfortunately melts at about 6,000 deg, could have its temperature increased to that of the surface of the sun (about 11,000 deg), the light would be essentially the same as sunlight. If now we could keep on raising the temperature of our lamp filament to that of the center of the sun and most of the other stars, some 90 million deg F, according to the estimates of Jeans and Eddington, our lamp filament would become an intense source of X rays. While the X rays occur on earth only as a man-made product, they must play a major rôle in the interior of the stars, for it appears to be the pressure which these X rays exert on the surrounding matter which resists the inward pull of gravitational attraction and so determines the size of the stars.

The riddle of the nature of X rays was solved by Professor Laue, of Germany, who found, from their behavior on passing through crystalline material (rock salt, for example), that they were like ordinary light and like radio waves, except that their wave-length was much shorter. The wave-length of these radio waves is about $^1/_4$ mile, that of ordinary light is about a 50th of the thickness of tissue paper, and that of the X rays is about one 10,000th that of ordinary light.

The wave-length of the X rays is determined by the voltage applied to the tube, and is halved every time the voltage is doubled. The higher the voltage used, and the shorter the resultant wave-length, the more penetrating are the X rays. For medical diagnosis, the voltage used is adapted to the thickness of the part to be radiographed, and ranges from say, 60,000 to 120,000. The same X ray methods which have been used for medical diagnosis have proved useful for the examination of many of the different materials used in industry.

X rays in sufficient quantity are apparently capable of destroying all living tissues both plant and animal. It has fortunately been possible to develop sufficiently sensitive photographic film and fluoroscopic screens so that the amount of radiation to which a human patient must be exposed for X ray diagnosis is not injurious. The fact of their physiological action has led to another important medical application; namely, the therapeutic treatment of various diseased conditions.

In the biological field the X rays seem destined to play a very important rôle, as they have been shown to be capable of producing profound changes, especially in germ cells, and so affecting heredity in both plants and animals. They bring about in the laboratory just such changes as are produced in nature by the still shorter wave-length, gamma rays, and it seems not unlikely that these gamma rays, assisted perhaps by the cosmic rays, have been one of the most important factors in the evolution of our varied plant and animal life.

In the field of physical science the X rays have rendered us their greatest service by enormously increasing our knowledge of the structure of matter. They have taught us how the atoms which constitute matter are arranged, and have permitted us to measure the distances between these atoms. They have taken us within the atom and revealed to us much of its internal structure. They have showed us how the atoms of the different elements differ among themselves, and have given us a simple system for the arrangement and classification of the elements. They have indicated to us vacancies in this system and, in the cases of hafnium, rhenium, mazurium, and illinium, have helped us to discover missing members. Finally, through the increased knowledge which they have given us of atomic phenomena, they have greatly advanced our understanding of cosmic phenomena.

Recent Developments in Electric Power Generation

Following its previously adopted custom, the A.I.E.E. committee on power generation presents in this report a survey of developments in the generation of electric power during the past 2 years. General trends in steam plant practice have been toward higher pressures and temperatures; trends in power plant design have been toward simplification, rehabilitation, and increased economy of operation. In the hydro-electric field an increasing application of the propeller type turbine in low head plants has been noted, with some indication that in the future the regenerative cycle may have a wider application in the United States than it has had in the past.

FOLLOWING the intention announced in last year's report, the A.I.E.E. committee on power generation* continued to promote the discussion of matters in the field of electric power generation from a retrospective and generally analytical viewpoint, for the particular purpose of weighing recent tendencies in design to the end that profitable avenues of progress may be revealed and utilized when capital investment again is resumed on a hitherto normal scale in the construction of power-generating facilities. The committee does not believe that the present lull in construction activities should result in a stagnation of the directive thought that will be responsible for the design of power stations in the future, nor in the entire diversion of such ability to the problems of minor improvements and operation under reduced output, commendable and necessary as such duties may be. It is glad to report a very real interest among responsible engineers in the consideration of the major principles governing the economic generation of power, and to note that fundamental thought and work are being actively continued.

Full text of the annual report for 1932 of the A.I.E.E. committee on power generation. *Not published in pamphlet form.*

*Committee on power generation: †J. R. Baker, *chairman;* F. A. Allner, †F. A. Annett, †A. E. Bauhan, †J. B. Crane, E. W. Dillard, J. H. Ferry, N. E. Funk, W. S. Gorsuch, F. C. Hanker, J. P. Hogan, F. H. Hollister, A. H. Hull, †D. C. Jackson, †A. V. Karpov, †H. W. Leitch, A. H. Lovell, †I. E. Moultrop, J. M. Oliver, †A. L. Penniman, Jr., G. G. Post, R. C. Powell, †F. A. Scheffler, F. O. Schnure, R. E. B. Sharp, A. E. Silver, †A. R. Smith, E. C. Stone, †C. A. Powel (alternate for F. C. Hanker).

† Members of subcommittee on report.

3. For all numbered references see bibliography.

The committee calls attention in this report to 4 papers[3] presented at the 1932 A.I.E.E. summer convention, Cleveland, Ohio, that discuss current practices in the operation of power systems which include several generating plants. The success in the operating interconnection among a group of plants to supply a load area has been one of the notable achievements in the last decade in the field of power generation. These 4 papers summarize present ideas about the most effective methods of operating such systems to obtain maximum reliability in service and minimum operating cost. They also indicate a reduction in operating expenses on representative power-generating systems in the immediate past, and give assurance that the improvement in operating economy has not been at the expense of unjustified carrying charges.

A group of 4 papers[83,90,97,98] on hydroelectric power generation (presented at the Baltimore, Md., district meeting, in October 1932) included: a comprehensive survey of the economics of water power developments; analyzed the possibilities of the regenerative type hydroelectric plant; discussed the development of the latest design of water turbine; and described a recently constructed plant of large magnitude that contains the most powerful Kaplan turbines yet built and the largest in physical dimensions so far installed on this continent. A notable hydroelectric plant on the St. Lawrence River of unusual magnitude and incorporating novel features for the production and distribution of 25- and 60-cycle energy is discussed in a paper[81] presented at the 1933 summer convention.

The salient features and the economics of high pressure and high temperature steam-electric power plants were analyzed in a paper[39] presented at the 1933 winter convention. In the discussion mention was made of the modern method of fabricating pressure vessels by means of the electric arc.

Although the volume of generating plant construction is small in the plants that have been designed recently, contemporary ideas as to economy in investment and operation are developed to an extent that is probably in advance of anything hitherto attempted. Progress in the use of large boilers and turbines operating at 1,300 lb per sq in. and 850 deg F with a ratio of one boiler per turbine is exemplified by the Port Washington plant of the Milwaukee (Wis.) Electric Railway and Light Company. The design of this plant is described in a paper[30] presented at the 1933 A.I.E.E. summer convention. Another paper[42] presented at the same convention discusses the rehabilitation of a low pressure steam power plant on a large system, which had been practically retired except for peak service. This re-

habilitation was accomplished by installing a turbine to operate with throttle steam at 655 lb per sq in. and 850 deg F, and to exhaust at pressures up to 220 lb per sq in. into the mains that supply the low pressure turbines. The compounding of the new turbine upon the old station has made an almost obsolete plant the most efficient on the system.

A subcommittee under chairmanship of F. H. Hollister has in preparation a symposium on the subject "Switching Energy at Modern High-Capacity Generating Plants," which is contemplated for presentation at the 1934 A.I.E.E. winter convention. Experience during the more recent years where particular generator, bus, and switching arrangements are used, will be analyzed, the limitations discussed, and the probable trends noted.

The committee recommends also that the subject of regenerative hydroelectric plants presents opportunity for the assembly of valuable experience derived in European plants. The use of this type of plant has been more extensive in Europe than in this country, but some engineers believe that the future will witness an increasing number of such plants in the United States.

The custom of the committee has been to prepare a detailed progress report and bibliography in its field at biennial intervals; the remainder of this report therefore summarizes matters of interest that have developed or culminated in the past 2 years.

I—Volume of Power Generation

When the 1931 report of the power generation committee was written, the United States was suffering from a 2 years' drought and a business depression. By the end of that year rainfall quite generally had become normal. From 1921 to 1929 the amount of power generated in public utility plants in the United States increased from 41 to nearly 97.5 billion kwhr, a gain of 138 per cent in 8 years. Since 1929 the volume of power generated has dropped to 84 billion kwhr, a decrease of 13.9 per cent in 3 years.

Beginning with 1928 to the end of 1931, hydro-generated power decreased from a maximum of nearly 35.0 to 30.6 billion kwhr, notwithstanding that during that period the installed capacity in hydroelectric plants increased over 2 million hp. Last year was a fairly good water year. Hydro-generation increased to near the 1928 figure and represented a larger part of the total generation than for previous years, being 40.5 per cent. The increase in hydro-generated power with a decreasing total volume of generation has caused a heavy loss in output from fuel burning plants, a drop of 11.9 billion kwhr occurring during 1931 and 1932.

II—Generating Plant Construction Progress

Although the volume of generation by utility plants has decreased 13.9 per cent in the last 3 years, installed capacity in these plants has increased 5 million kw, or about 20 per cent. The increase in steam plant capacity amounted to about 3.5 million kw, and in hydroelectric stations, to 1.5 million kw. This large capacity increase represents the completion of construction programs under way at the beginning of the depression. Work has been practically completed on most of the projects initiated within the past 2 years. The present total of central-station generating-plant construction budgets is lower than in any year during the last decade.

The steam-electric generating plant capacity added in 1931 was about $^1/_3$ as great as in 1930 when over 2 million kw was placed in operation; in 1932 the new capacity was slightly smaller in amount

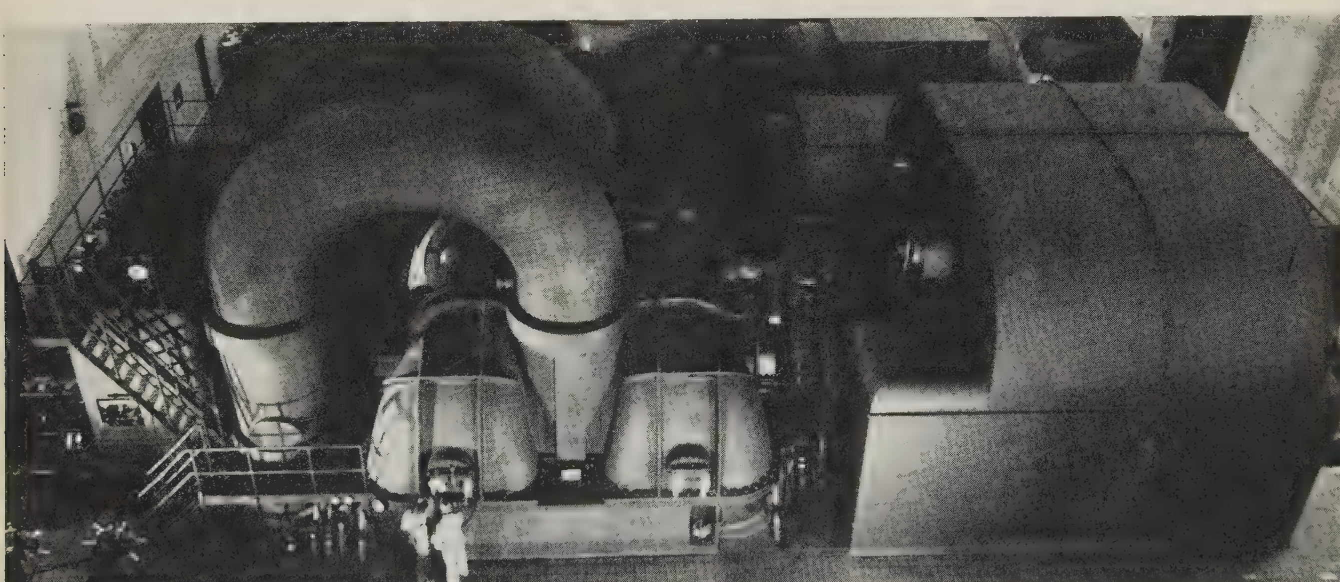
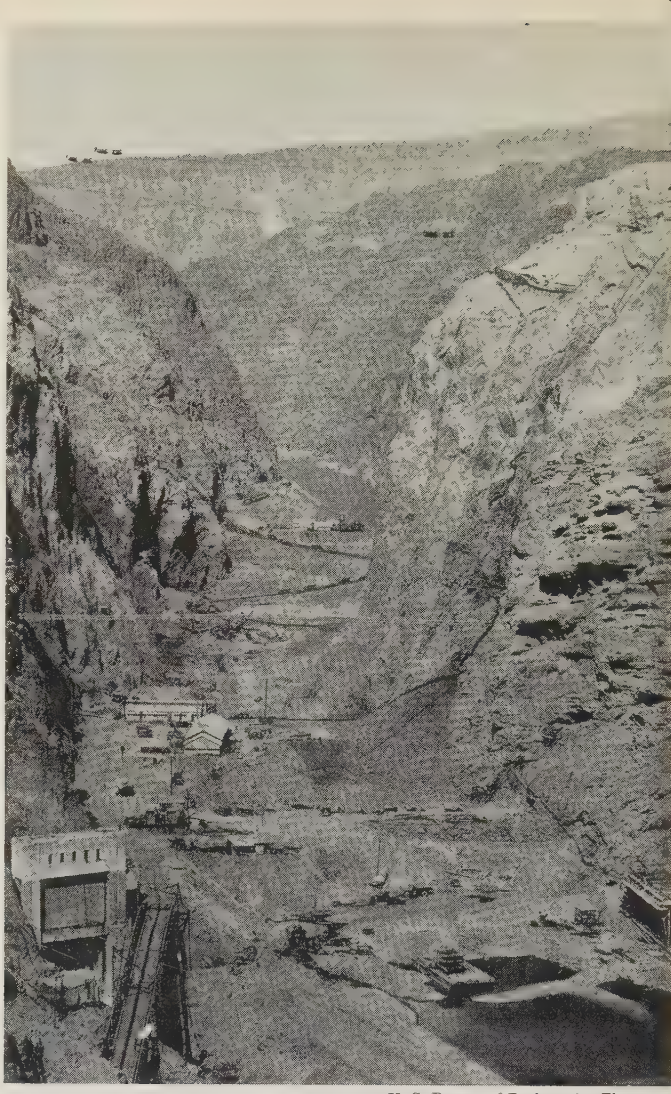


Photo by Arthur E. Cheesman, New York, N. Y.

One of the 2 160,000-kw tandem-compound turbine-generators installed in the Hudson Avenue station of the Brooklyn (N. Y.) Edison Company during 1932. The unit operates at 1,800 rpm, is 85 ft 8 in. long, 24 ft wide, and stands 24 ft above floor line

than in 1931. The 1931 installations were about equally divided between existing plants and newly constructed plants; in 1932, additions to 3 major plants comprised practically the entire new steam plant capacity placed in operation. Only 2 new major steam plants are now under construction; large extensions that have been initiated to 2 existing steam plants are being postponed.

In the water power field, the new capacity initially operated in 1931 in the United States exceeded slightly that in 1930; Canadian installations in 1931 also were at or above normal volume. The decrease in added capacity in 1932 was very marked in the United States when the total of several small installations was only about $^1/_9$ of the increase in 1931; the initial operation of the large Beauharnois plant in Canada resulted in new capacity there somewhat in excess of $^1/_3$ of that in 1931. Only one important project, Boulder Dam, is actively under construction in the United States. There are several plants, totaling about 750,000 hp, on which work was started but has been postponed temporarily. Not one important contract for hydraulic turbines was let in 1932 in the United States and Canada, which is an indication of how seriously water power developments have been curtailed. This year the contract for the Boulder Dam turbines is the only major one to be placed. Unless work soon is started on some of the larger projects now being considered, hydroelectric construction probably will be of small volume for the next few years.



U. S. Bureau of Reclamation Photo

Boulder Dam, looking upstream through Black Canyon toward damsite, prior to beginning of excavation of middle gorge. The first concrete was poured early in June

III—Interconnection

While the interconnection of power systems already accomplished has continued to promote economy in power generation in the 2 years elapsed since the last report, but few additional notable interconnections have been established. A major one has been between the systems of the Niagara-Hudson Power Company (N. Y.) and of the companies affiliated with the Consolidated Gas Company in New York City. This interconnection, which has been described in *Electrical World* of July 18, 1931, consists essentially of 4 110-kv circuits extending from the Mohawk Valley to a switching station at Pleasant Valley, about midway between Albany and New York City, at which point the voltage is changed to 132 kv. From Pleasant Valley 2 132-kv circuits will extend into the New York City system through existing 132-kv underground cables. The Pleasant Valley transformation is by means of 2 banks of auto-transformers, each having a capacity of 100,000 kva. Synchronous condensers are connected to tertiary windings in these transformers. The parties to this interconnection expect to realize a saving in generating capacity requirements by the exchange of emergency service. Also, economy flow and storage power transactions will be made possible.

Another interconnection which is noteworthy in several respects is the 220-kv interconnection between Baltimore, Md., and Washington, D. C., placed in service early this year. It consists of a tap on the 220-kv single circuit from the Safe Harbor hydroelectric development to Baltimore. It has been justified primarily by storage power transactions; that is, it in effect creates additional generating capacity by the proper manipulation of the steam generation and hydroelectric storage. This interconnection of course, also, will serve for the purposes of emergency service and economy flow.

During the past 2 years, power system operators have been more largely concerned with improvements of operating technique and a careful combing over of possible economies that might be realized from existing interconnections.

Frequency and Tie Line Load Control

One of the problems that has been receiving considerable attention, especially where several systems covering an extensive area with many power stations are involved, has been that of tie-line power-flow control with its related subjects of frequency

and time control. The admirable papers of Sporn and Marquis, and of Purcell and Powell (see bibliography) exemplify the thought that has been given to this problem, and portray its status.

Elementally in a group of interconnected systems, where control of the tie line flow is necessary because of physical limitations or desired in order to meet contractual requirements, frequency (and time indication) must be regulated by some *one* system. Tie line flow is regulated by the other systems—each regulating the flow in only one designated tie line, usually in one of the lines with which it is directly connected—by variation of generator phase angle through governor control.

If 2 or more of the interconnections form a loop, the foregoing regulating scheme must be supplemented by a phase shifting device in one of the interconnections forming a part of that loop. The flow in one of the interconnections of that loop, usually although not necessarily the one in which the phase shifter is situated, must be controlled by the phase shifter.

In some groups of systems, manual operation under such a plan is satisfactory, especially where the controlled quantities are indicated on meters before the eyes of the respective operators controlling those quantities as against being relayed to them by telephone messages from distant points. In other interconnected groups, where conditions are not so favorable, the transient conditions caused by load variations and emergency conditions impose load swings on the frequency regulating station or on the tie lines, which exceed the limits of the equipment or are otherwise undesirable.

To the extent that these difficulties are caused by the limitations of manual control, automatic frequency control and tie-line load control devices have been developed and successfully applied. Where the difficulty has been the inability of the frequency regulating station to handle its task, effort has been directed toward distributing the frequency regulating function to several stations in different parts of the interconnected system. Automatic frequency regulators so distributed have been adjusted to operate successfully in parallel and, aside from distributing the frequency regulating burden, have eliminated erratic behavior of tie line flow. But where complete tie line control also is desired, they must be coordinated in their operation with tie-line load control devices. Development work on such coordination is in progress.

In the case of tie line control, whether it be manual or automatic, difficulties arise when the controlling station is remote from the controlled point; perhaps telemetering principles will be resorted to in such cases. A case in point is an interconnection in northern New Jersey between the systems of the Public Service Electric and Gas Company and the New Jersey Power and Light Company, the flow over which at times is being regulated by the Conowingo hydroelectric plant in Maryland some 130 miles away. Communication between the controlled and the controlling points is by telephone. The control, of course, is rather rough, but further refinements in this case are not warranted.

Phase Shifters

The problem of power flow control in interconnection loops referred to previously will become of increasing importance if and when business conditions warrant the installation of additional interconnections between systems which at present are directly or indirectly interconnected.

Phase shifting by quadrature additions to voltage either in the interconnection transformers themselves or in separate series units is, of course, technically a very satisfactory solution. But such equipment adds considerably to the cost of an interconnection and may make it uneconomic. Consider the case of Company *A* which for several years has had a low voltage interconnection with Company *B*; Company *C*, which is interconnected with Company *A*, desires to establish a large, important, high voltage interconnection with Company *D*, which in turn is tied in with Company *B*. The loop thus formed renders some one of the original interconnections inoperative, unless phase shifting equipment be installed. Since the cost of phase shifting equipment is proportional to the size and voltage of the interconnection, the cost of installing such equipment in the new interconnection may be prohibitive; perhaps it may be installed less expensively in one of the older ties. If so, questions of ownership, financing, cost responsibility, and cooperative control become complicated.

In some cases it may be possible to omit phase shifters, if the resulting uncontrolled power flow is physically tolerable and if satisfactory contractual and billing arrangements among the companies involved can be made. Contractual difficulties usually are slight when only 2 companies are involved, but if there are 3 or more companies in the loop, such solutions are not always available.

Note should be made of the rather large phase shifting transformers in use by the Texas Power and Light Company at their Temple substation, as described in the *Electrical World*, November 22, 1930. Transformers of this type can be arranged to serve either as phase shifters or as voltage-ratio changers, which may be desirable as changes in contractual or corporate relationships occur. So far as known the largest phase shifter yet built will handle the output of a 100,000-kva 26/66-kv transformer bank on a feeder between the State Line and Calumet stations in Chicago, Ill.

It is to be expected that if improved business conditions bring about additional interconnections, phase shifting devices will be required in more cases than in the past. Even where loops are not formed, the possibility of their occurring at a future time may call for designs which will permit the later installation of phase shifters.

Time Regulation

Either by directed effort, or as a result of the installation of automatic equipment to facilitate power flow control, the time regulation of some systems has reached a point which is beyond practical requirements. The systems of the North Atlantic

Pleasant Valley (N. Y.) substation of the New York Power & Light Company, where the Niagara-Hudson and New York Edison transmission systems are interconnected through 2 banks of 110/132-kv 100,000-kva auto-transformers

seaboard are operating with a time error not exceeding 20 sec. Another group of interconnected systems is said to be capable of operating with a frequency deviation not exceeding $^1/_{40}$ cycle (at 60 cycles) and a cumulative time error of not to exceed 3 sec.

Economy

The general search for savings in all branches of power system operation has not slighted any possibility for such savings arising from interconnection. There has been increasing appreciation of the behavior of power station production expense, particularly in the matter of distinguishing between those costs that are proportional to output and those that are not. The article on "Calculating Savings from Power Interchange" by E. C. Brown, appearing in the *Electrical World* of February 20, 1932, outlines in considerable detail the methods used in determining savings in the Connecticut Valley Power Exchange. P. B. Juhnke, in *Electrical World*, August 22, 1931, outlines perfections which have been made in the contractual relations of the companies operating in the Chicago district.

Nomenclature

As a result of discussion of the 1930 summer-convention papers, the joint subcommittee on the subject of interconnection (formed by representatives of the committee on power generation and other interested committees) has formulated definitions of the various types of service rendered by interconnecting facilities. The joint subcommittee, however, has not yet taken steps toward their official adoption.

Industrial Interconnections

Exigencies of the time have occasioned considerable study of the principles of interconnection between utility systems and the power plants of industrial customers. Industries utilizing quantities of process steam or having available by-product fuel have shown continued interest in by-product power production by the installation of high pressure boilers with extraction turbine-generating apparatus. This development frequently results in the definite cooperation between industry and utility in the production of both steam and electric power. To the several notable instances mentioned in the 1931 report of the power generation committee should be added that of the Schenectady mercury-vapor-steam plant which is interconnected with the lines of the local utility. Principles involved in analyzing the services and economic results of such interconnections do not differ from those which apply to interconnections between power companies. However, in arriving at contractual arrangements with such industrial plants, the commercial policies of the power companies cannot be overlooked. There must be coordination between these arrangements and the rate schedules of the companies. The universality of rate schedules interferes with a full general application of inter-utility interconnection principles to dealings with customers. While many special arrangements have been entered into with industrials, they have been principally with the larger plants. It is felt that interconnection with the many smaller industrial plants must be approached more from the standpoint of introducing interconnection principles into rate schedule modifications and applying them generally, rather than by a multiplicity of special arrangements with the individual consumers.

IV—Steam Plant Practice in the United States

General trends in steam power plant design during the last 2 years have been toward plant simplification, rehabilitation, and increased economy of operation, rather than to further elaboration in new or existing stations. Operating steam temperatures have continued to increase and several stations now use steam at 800 to 850 deg F. As now accepted, the upper limit of steam temperatures is 850 deg F, but experiments with steam at higher temperatures are being carried forward as, for example, at the Delray Station of the Detroit (Mich.) Edison Company.

There has been no tendency during the past 2 years toward the use of steam at higher pressures, but during this period several 1,200- to 1,400-lb plants have been in successful operation. Only minor improvements in the design and construction of equipment to operate at those pressures have been necessary. While the foregoing is the generally accepted maximum pressure range for power plant

practice today, investigation of steam generation at higher pressures has proceeded actively. Experimental series drumless boilers for steam pressures up to 3,500 and 5,000 lb per sq in., respectively, are in their second year of operation at Purdue University and at the plant of a boiler manufacturer. Studies have been made of heat transfer, of the flow of water-steam mixtures, and of the heat content of steam at high pressures. Several manufacturers have constructed steam generators for pressures as high as 2,500 lb per sq in. and for temperatures up to 1,000 deg F, for producing relatively small quantities of steam to be used in testing instruments and fittings. Experience being gained in the construction and operation of this high pressure equipment may prepare the way for the next increase in commercial pressures.

The fact that plants have been and are being operated successfully at the higher pressures mentioned warrants the further consideration of such pressures for new plants and the rehabilitation of old plants from the standpoint of first cost, economy of operation, reliability, and lack of operating difficulties. Since it has been proved that equipment can be successfully constructed for temperatures of 850 deg F, a relatively high economy can be secured by the use of 650-lb pressure without reheat. This is due in part to the increased operating temperatures that are possible. The adoption of the mercury cycle in an existing plant is essentially similar to the superposition of a high pressure (1,300 lb) turbine upon a lower pressure turbine system.

The trend toward plant simplification is characterized by the unit assembly arrangement in which a turbine is served by a single boiler. With the availability factor of modern boiler units rapidly approaching that of turbine units, there is a definite trend toward the use of boilers of high capacity with accompanying reduction in boiler plant investment. It is now common practice to install only 2 boilers per turbine in large plants, the Charles R. Huntley Station No. 2 of the Buffalo General Electric Company being an example. Consideration also is being given to the one-boiler-per-turbine layout; such an arrangement is used in the Port Washington Station of The Milwaukee Electric Railway and Light Company. There are no size limitations to this arrangement, as it is now possible to build a boiler unit with a capacity equal to the demands of any turbine unit.

Boilers

Boilers are now in successful service generating over 1 million lb of steam per hour per unit and it is possible, even feasible, to build units of 2 million lb of steam per hour each. The steam capacity of boilers per foot width of furnace has risen steadily until now units are under construction with capacities as high as 17,500 lb per hour per foot, and units of much greater capacities have been designed and proposed.

The single-pass sectional-header boiler, without economizer, air heater or induced draft fan, has made some progress in this country for low load factor plants, such as steam heating and reserve for hydroelectric plants, and for plants having good load factors where low cost fuels are used. Single-pass coverging-header boilers are used with economizers and air heaters for stations that are to operate at a relatively high load factor where it is desired to keep the draft loss for the unit down to a minimum with maximum heat transfer.

Welded drums now are permitted by the A.S.M.E. Boiler Code, making possible great progress in the adoption of this construction which is an important step forward in boiler design. The individual states are rapidly accepting this construction. Exploration of welded seams by means of X rays and gamma rays has kept pace with other advances in the welding art. Welded seams in plates up to $4^3/_4$-in. thickness now can be explored by X rays, and up to 6 in. by gamma rays.

Accurate steam temperature control for all conditions of load and operation is now desirable in many cases, the cost of metals and constructions necessitated by prevailing high temperatures making it desirable to operate at the upper design limits at all times. A method of such control is by means of a desuperheater located preferably in the intermediate position between the upper and lower sections of the superheater. The use of intermediate desuperheaters has a further advantage in that the quantity of alloy superheater tubes usually necessary when higher temperatures are encountered is held to a minimum by reducing the temperature of the steam before, and not after, it reaches the superheater outlet. Another method of temperature control is the combination of a convection superheater located in the boiler passes with a radiant superheater placed on the walls of a furnace designed for a moderate heat-release rate per unit of furnace volume. Temperature control by a swinging baffle in the path of the furnace gases, causing these gases to sweep more or less superheater surface, also has found application.

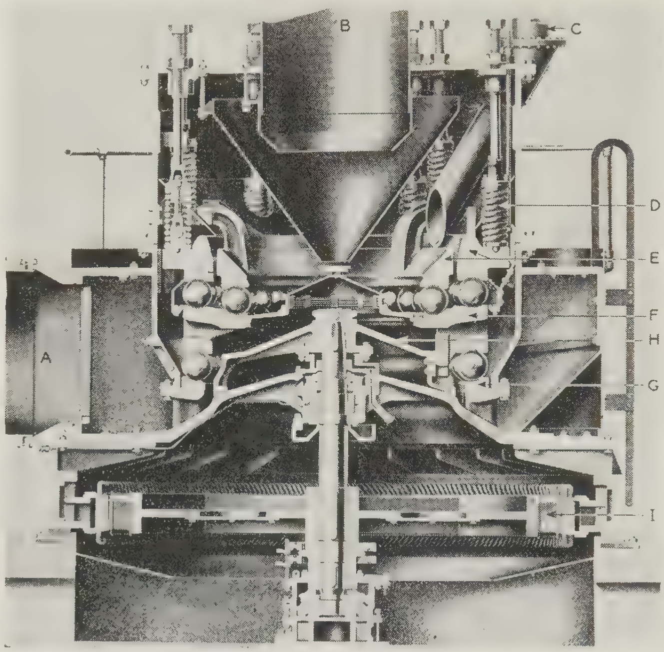
It has been found increasingly important in many central station plants to reduce materially the quantity of moisture carried over by the steam, and to reduce the amount of solids passing through to the turbine in order to prevent trouble from the deposit of solids on the turbine blading. One of the means by which this is being accomplished is the use of a new steam scrubber installed in the boiler drum, which washes the outgoing steam with the incoming boiler feedwater. Thus the solids, which ordinarily would be carried over by the moisture in the steam, are washed out and any moisture remaining in the steam is cleaner and freer of solids.

Firing Methods

Methods of firing fuel have undergone no major developments during the past 2 years, although in many cases conversion has been made from pulverized coal firing, and in instances from stoker firing, to gas or oil firing. The completion of pipe lines from Texas and Oklahoma to Chicago has influenced the use of natural gas throughout the Mis-

sissippi Valley, in combination oil, coal, or gas burners.

Improvements in large stokers have been apparent in recent years. Developments in stoker fired equipment include the trend toward larger units and the increased use of zoned air-control. The latter method of operation results in higher combustion rates and steaming capacities of boilers. Tests on an experimental stoker installation under Philadelphia (Pa.) Electric Company's No. 8 boiler at Chester Station have indicated that a dry coal burning rate of about 72 lb per sq ft of projected grate area could be maintained for about 4 or 5 hr. This represented a fuel burning rate of 78 lb per sq ft, resulting from the return to the stoker of about 6 lb per sq ft of cinder collected at the back of the boiler. The tests indicated that continuous dry coal burning rates should be limited to about 60 lb per sq ft of projected grate area. Delray No. 3 of the Detroit (Mich.) Edison Company, also by use of zoned air-control has increased boiler efficiencies by 3 per cent on the average. Air zoning is accomplished by installing a number of individual wind boxes with adjustable damper-controlled entrance orifices under each retort. Air is in effect measured to each wind box, and the metering may be made the basis of automatic control.



Section of Babcock & Wilcox type B pulverizer installed at the Kips Bay station of the New York (N. Y.) Steam Corporation

This mill pulverizes 50 tons per hour of 70 grindability coal from the Pittsburgh Seam to a fineness of 70 per cent through a 200 mesh screen and 98 per cent through a 40 mesh screen

A. Separating air inlet
B. Pulverized coal outlet
C. Coal inlet
D. Pressure regulating springs
E. Stationary rings
F. Rotating ring
G. Stationary ring
H. Driving yoke
I. Vertical synchronous motor

Underfeed stokers are now available which with single-ended firing are capable of handling up to 18 million Btu per hour in high grade coal per foot width of furnace, and pulverized coal burners and furnaces now are being installed for single-ended firing as high as 25 million Btu per hour input per foot width of furnace.

The slag-tap furnace has proved to be important in permitting the most economic design of boiler unit, because of the high permissible rate of heat input per foot width of furnace and the lower setting height required. The slag-tap furnace is adapted especially to the use of low grade coals. There are now in excess of 60 slag-tap furnaces in operation in this country. Difficulties initially encountered with this type of furnace have been overcome by the use of water cooled furnace floors.

Difficulties with slag-tap furnace installations caused by the excessive slagging of boiler tubes with molten ash have resulted recently in the development of dust screen tubes to which studs are welded and covered with refractory material, for the purpose of presenting a surface to which ash dust would adhere and fuse to the point where it would drop off and thus maintain a stable surface. This construction is being applied also to furnace walls.

The universal, completely metal-cooled furnace in which solid, liquid, and gaseous fuels can be burned separately, or in combination, is being approached in several large central stations and allowed for in others. This design is made possible by the development of combination fuel burners for firing through water-cooled furnace walls; similar burners have been used also for vertical firing.

Progress has been made in both the direct fired and the storage system of pulverized fuel firing, each method having economic applications which can be determined best by a careful analysis of the conditions under which the plant is to operate.

The construction of a pulverizer with a capacity of over 50 tons of coal per hour installed in the Kips Bay Station of the New York (N. Y.) Steam Corporation was an outstanding development of the period. A unique driving mechanism is adapted to the 50-ton mill. No gearing is used, and the mill shaft is connected directly to the rotor of a 500-hp vertical synchronous motor at 72 rpm. The mill base rests directly on the stator frame. To overcome the difficulty of mill starting, especially when partly filled with coal, unusually high starting and pull-in torques were specified; overvoltage starting is used to obtain these.

Turbine-Generators

The trend toward large capacity single-shaft turbine-generators noted in the last report apparently has continued in this country, although the number of machines purchased lately has been few. The 2-cylinder tandem-compound unit appears to be the preferred type at present for large capacities; a 150,000-kw 3-cylinder tandem-compound unit for 1,200-lb pressure and 825-deg F initial and resuperheat steam temperature was delivered in 1932.

Five vertical cross-compound units are in operation in this country at 1,200-lb initial pressure.

Turbine operating experience during the past 2 years apparently has shown an increased degree of reliability which can be attributed definitely to improvement in the design of turbine details, and not to the lessened use of turbine-generators. There is concrete evidence that breakage of turbine blading because of vibration is being diminished. Other difficulties, however, are arising in consequence of: the use of higher steam pressures and temperatures; greater capacities requiring higher blade speeds; the desire to keep turbine and building investment to a minimum by using single-cylinder units of large output; and in some cases, the necessity of operating units at reduced load. Troubles caused by these and other factors are: the erosion of turbine blading by moisture in the steam; deposits on turbine blading; difficulty in starting units after shutdown of a few hours; and oil fires.

While boiler water conditioning or control is usually desirable for all pressures, frequent turbine outages and reduction in turbine capacity because of blade deposits following the use of high steam pressure resulted in more emphasis on this phase of plant operation. The purpose is mainly for the reduction or elimination of scale-forming and corrosive substances from the water, and the maintenance of the proper sulphate to carbonate ratio to inhibit embrittlement of the boiler metal; although related is the prevention of foaming, priming, and carry-over, which results in deposits in superheater tubes and on turbine blading.

Tip speeds of turbine blading have been increased in recent instances to over 1,200 ft per second. Erosion of the blading by moisture in the steam increases with the speed of the blades, and now is recognized as a problem requiring solution. A comparatively large amount of moisture in the steam in the low pressure end of turbines seems to result from economic turbine design. Designs have been made for internal arrangements to drain the moisture from the turbine as it forms, but to date such efforts have been only partially successful. Higher initial steam temperatures are beneficial for the purpose, as well as reheating of the steam during expansion through the turbine. In all cases in this country except 6 turbines, reheating has been carried out with the use of either tandem- or cross-compound arrangement of turbine cylinders. Turbine manufacturers are making intensive studies of the resistance of blade materials to erosion and corrosion. Plating and coating of blades, and the attachment of strips of erosion resisting materials such as stellite to the wearing edge of the blade, have been tried. Laboratory tests with steam and water jets have indicated promising characteristics for steels which were surface-hardened by nitriding. Single turbines having blades protected by about 30 different methods and materials now are being operated to compare the endurance of the blades under actual operating conditions.

The use of higher steam temperatures, reduced internal clearances of turbines, turbine cylinders of larger capacity, and the necessity of frequent stopping and starting have resulted in difficulty in the starting of turbines after short idle periods. Uuequal temperature distribution throughout the turbine following shutdown has caused sufficient deformation of the turbine spindle and eccentricity of its axis to produce vibration if started in this condition. The use of a turning gear in conjunction with high pressure oil for floating the turbine shaft in its bearings has been of service in this connection; this practice has substantially reduced the time necessary to bring units to full speed, and has aided in maintaining close internal clearances and thus improving steam economy.

Another development along the same line has been that of turbine supervisory instruments for remote indication of turbine performance. These instruments will be useful also for outdoor generating equipment. The instruments will indicate or record turbine speed, shaft eccentricity, movement of parts as the result of temperature changes, vibration, and noise intensity resulting from improper contact of parts.

Recent oil fires in turbine plants using high temperature steam have stressed the necessity for better safeguards against this type of damage. Separation of the oil systems employed for lubrication and governing has been proposed, also the use of non-inflammable liquids. Redesign of the lubricating and governing systems also is being considered with the view of strengthening structural details and of preventing the access of oil to regions of high temperature in the event of casualties.

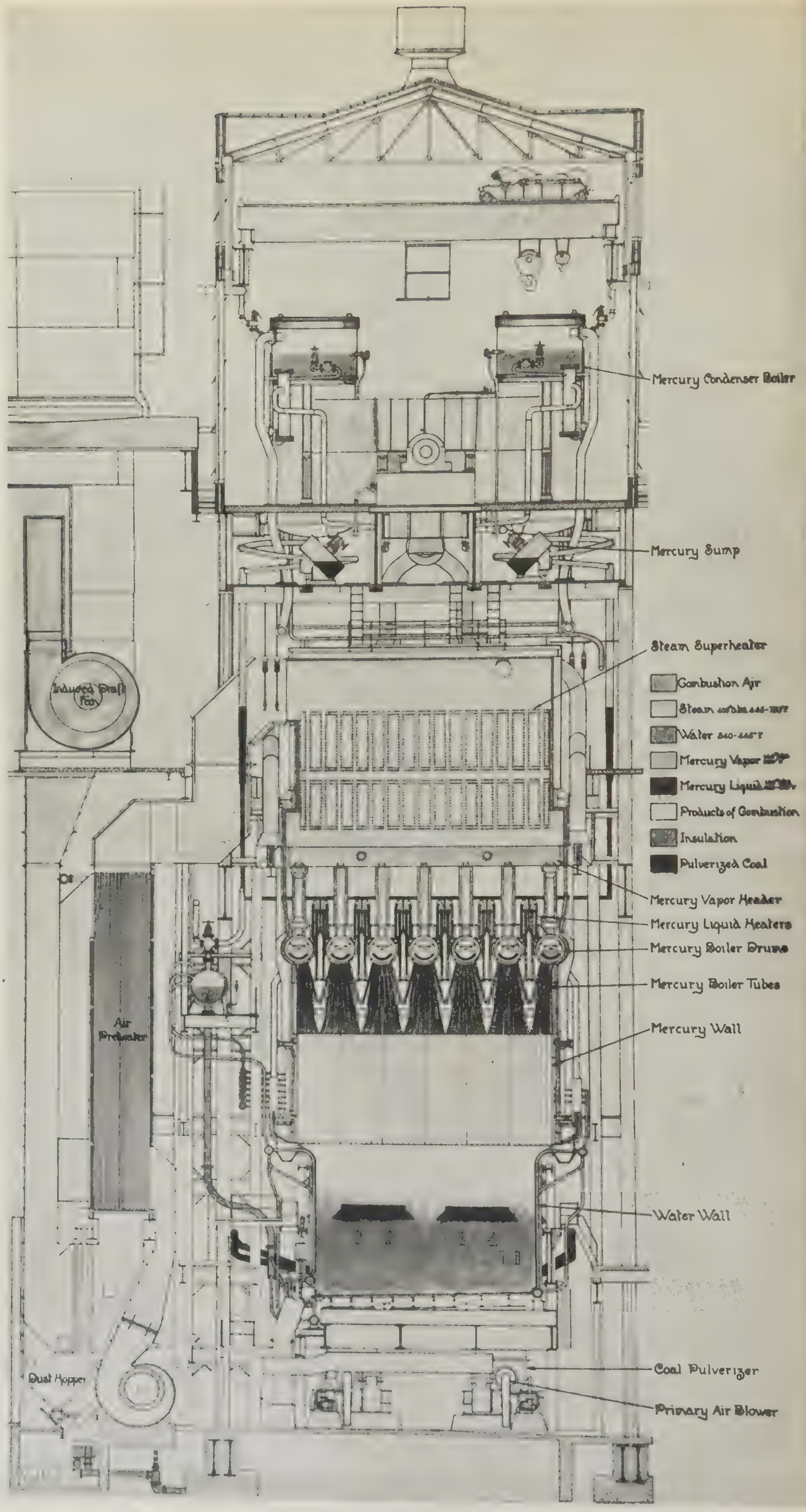
Welding has found increasing application in plant design in addition to the fabrication of boiler drums mentioned previously. High-pressure high-temperature steam lines are being welded and stress relieved in place. Many turbine parts now are being fabricated by the welding of plates and shapes, with the elimination of castings. The development of X ray testing for shop processes has helped the introduction of welding in the field of turbine manufacture.

Condenser development has continued along the lines followed for several years, although the trend as to reduction in condenser surface per unit of turbine capacity has about stopped. The largest condenser of welded construction, 65,000 sq ft, recently was installed in the Kearny Plant of the Public Service (N. J.) Electric and Gas Company. The trend in favor of single-pass condensers of large size has continued; the largest condensers of this design were installed in the Hudson Avenue Plant of the Brooklyn Edison Company, where turbines of 160,000-kw capacity exhaust into single-pass condensers of 101,000 sq ft each. Tubes with an active length of 30 ft are used in these condensers, which is the longest installed to date. Rolling of tubes in both tube sheets is being adopted more widely, with resultant benefit throughout the steam and feed water cycle. Chlorination of condenser water for inhibiting sliming and algae growth in condenser tubes, has been developed to a practical basis, and maintains condenser tubes in a greater state of cleanliness over longer periods resulting in increased

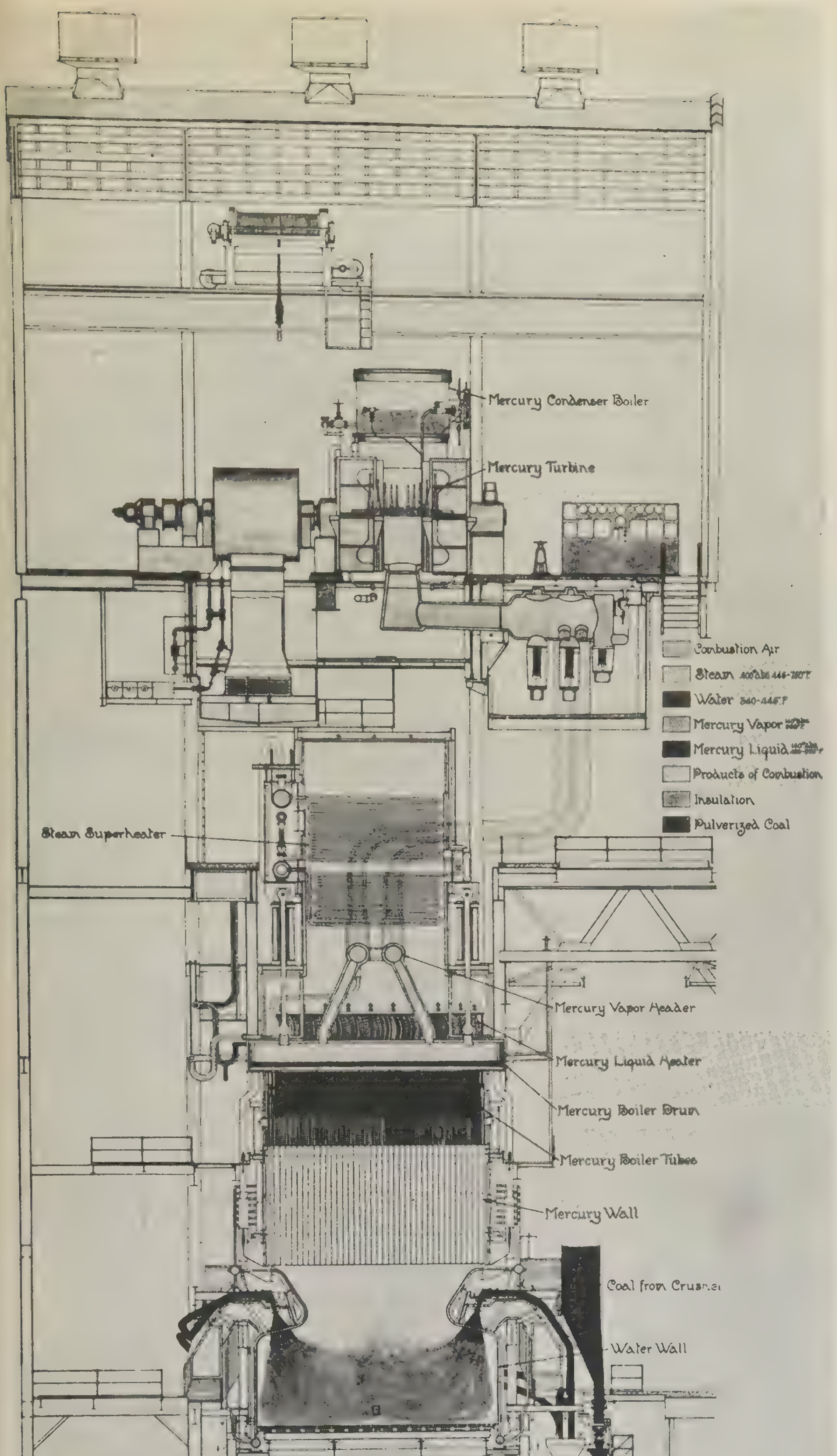
turbine availability, reduced manual cleaning of tubes, and increased turbine economy.

Since the 1931 report of this committee there has been an increase in this country in the capacity rating of turbine-generators with a speed of 3,600 rpm. Single-cylinder partial-expansion or back-pressure units now are in service having ratings up to 18,000 kw. Tandem-compound units of 15,000-kw rating are in use; these expand to normal condenser pressure. Tandem-compound machines of 25,000-kw capacity are under construction.

Generator purchases during the past 2 years have been too few to warrant additional conclusions, beyond those noted in the last report, about the use of higher generator voltages. It appears though that increased attention is being given to the subject of the most economic generating voltage; the advisability of holding to established voltages is being questioned, particularly where generators are connected directly through transformers to the transmission system. The development of a 36-kv 31,250-kva turbine-generator for installation in the Langerbrugge power plant in Belgium records an increased generating voltage in European practice over the 33-kv generators installed in 1929 in the Brimsdown Plant, England. Considerable study has been given to the problem of protecting generators connected directly to overhead lines against voltage surges. The increased knowledge of the nature and magnitude of surges and reflections obtained by the use of the cathode ray oscillograph has made it possible to apply protection by means of suitable lightning arresters and capacitors with some degree of assurance.



Vertical section of the General Electric mercury-steam equipment installed at the Kearny station of the Public Service (N. J.) Electric & Gas Company



Vertical section of the General Electric mercury-steam equipment installed at the Kearny station of the Public Service (N. J.) Electric & Gas Company

Developmental Work

Diphenyl compounds, which have been in considerable use as heat-transfer mediums in the chemical industry, were adopted for air preheating at the Bremo Bluff Station of the Virginia Public Service Company, because the extreme height of the units makes the flue gas outlet and source of heat for air preheating remote. The diphenyl compound is circulated between a heat absorbing element in the path of the flue gases and a heat releasing section in the air ducts of the furnace and mills. The relatively small dimensions of this equipment compared with the usual air preheater and duct work, resulted in a decrease in building height and volume. Reduced draft-fan power and radiation loss also were reported.

Improvement of methods for the removal of fly ash from stack gases has continued. After several years of development of an improved scrubbing process in the Kneeland Street Plant of the Edison Electric Illuminating Company of Boston, Mass., 95 per cent of the fly ash from the combustion of pulverized coal now can be removed. Experimental work is progressing steadily and it is expected that the effectiveness of the process will be improved further. At the Michigan City Station of the Northern Indiana Public Service Company an electrical precipitator of somewhat larger than normal size with correspondingly low gas velocities has given apparent efficiencies of dust removal ranging from 92.3 to 98.4 per cent.

A steam turbine in the Delray No. 3 Plant of the Detroit Edison Company has been operating with 1,000-deg F steam for a large portion of the time since the latter part of 1931. The installation consists of a 10,000-kw turbine with the generator terminals connected to the main station bus and operating under normal production

conditions. Steam for the unit is generated in the main station boilers at 400 lb and 700 deg F, is raised to 1,000 deg F in a separate oil fired superheater and arrives at the turbine throttle at 365-lb pressure. Turbine troubles due to such high temperature operation have been few and the high temperature equipment has good operating records; final conclusions about the installation, however, depend upon further experience.

The mercury-vapor-steam-electric power plant nearing completion at Schenectady, N. Y., represents an attempt out of the ordinary to eliminate all unnecessary expense in building construction. Static apparatus such as evaporators, deaerator, mercury-steam condenser-boilers, air preheaters, etc., have been placed out of doors as well as the 20,000-kw mercury turbine and the 6,000-kw pressure-reducing steam turbine. The steam boiler and the mercury boiler have been sheltered in glass as well as office space in the basement and coal unloading facilities; the latter have been housed to facilitate thawing in winter and to protect the adjacent factory from coal dust. Such housing as has been provided consists of factory-welded steel panels glazed in a manner quite as simple as the metal sheet lagging provided for apparatus regularly housed.

The mercury-vapor equipment in the South Meadow Station at Hartford, Conn., has been in continuous operation since changes were completed in 1932. The furnace now burns oil instead of powdered coal; steam is generated in the condenser boilers at the design pressure of 425 lb per sq in. and is used in the high pressure steam section of the station. For the 5-month period between June 1 and November 1, 1932, when sufficient load was available to load the mercury turbine fully, a total of 73,330,000 kwhr was generated at a heat rate less than 10,000 Btu per net kwhr; the load factor during that period was 87 per cent.

Since 1931 there have been mercury-vapor power installations of 20,000 kw each at the Schenectady Works of the General Electric Company and at the Kearny Station of the Public Service (N. J.) Electric and Gas Company. In each case operating conditions for the mercury turbines are as follows:

Initial pressure	125 lb per sq in. gage
Initial temperature	958 deg F
Exhaust pressure	3 in. mercury, absolute
Exhaust temperature	485 deg F

Steam generated in the condenser-boilers at both installations amounts to 325,000 lb per hr. At Kearny the steam is generated at 365 lb per sq in. gage and 750 deg F initial temperature, which is sufficient to generate 33,000 kw in a steam turbine. At Schenectady the steam is generated at 400 lb, 760 deg F initial temperature, is reduced in pressure to 200 lb by passing through a 6,000-kw reducing turbine and thereafter finds industrial use in the Schenectady Works of the General Electric Company. In each case the furnace is provided partially with mercury walls and partially with water walls. At Kearny the turbine is placed above the boiler as at Hartford so as to provide gravity return. At Schenectady the turbine is placed on the floor as in an ordinary power station, and the liquid mercury is pumped back to the boiler.

Operating Results

Despite the lack of new equipment and the decrease in power generation, the average coal consumption in the United States has fallen from 1.62 lb per kwhr in 1930 to 1.51 in 1932. This decrease may be accredited to the resultant gains from experimentation in higher steam temperatures and pressures; refinements in operating procedure; greater reliance on generating equipment and consequent reduction of number of units in service; high load factors on those operating; and the greater relative use of the more economical units. The trend toward unit assembly also is an effect of this increased reliability. The notable minimum heat rates achieved by the stations listed in Table I of the 1931 report have been maintained and lowered a per cent or 2 in certain instances during the past 2 years; but on the whole the heat rate of representative power plants has reached the point where little improvement can be expected without some major innovation in design. Steam temperatures approaching 1,000 deg F apparently promise a measure of thermal saving, although the mercury vapor cycle presents the greatest opportunity for heat reduction at the present time.

Plants Exemplifying Recent Designs

The evolution of Station A of the Pacific Gas & Electric Company, San Francisco, Calif., from its beginning in 1901 to the present rebuilt station, is interesting. The completed station of 260,000 kw will occupy no more space than the 18,000-kw equipment of 1905. During 1931, 2 50,000-kw vertical-compound turbine-generators began operation, and subsequent economies have resulted in overall station heat rates of less than 12,000 Btu per kwhr. The new boiler plant comprises 3 500,000-lb per hr cross-drum boilers, 2 of which have reheaters. Steam leaves the boilers at 1,400 lb per sq in. pressure and 750 deg F, and 350 lb per sq in. and 750 deg F after reheating. The high pressure unit running at 3,600 rpm is connected to a 12,500-kw generator; the low pressure unit running at 1,800 rpm is connected to a 37,500-kw generator with a 250-kw exciter on the same shaft. A feature of the reheating element is a steam reheater using saturated steam at 1,400-lb pressure in series with a flue-gas reheater. This has the effect of flattening the reheat curve at low ratings. Boiler firing is by natural gas and burners can use oil as standby fuel.

Hudson Avenue Station of the Brooklyn Edison Company enlarged its capacity by 320,000 kw which represents the major equipment installed in 1932. This plant now has a capacity of 770,000 kw and is the largest power station in the world. Eight bent-tube multi-drum boilers, with separate dry-steam drums, were installed. The output per boiler is 530,000 lb of steam per hour at 400 lb per sq in. and 750 deg F. A leading feature in the design of the boilers is the underfeed stokers which are 26 ft wide, with 15 retorts, and 26 ft 8 in. long, exceeding by 3 ft any stoker previously built. The stokers and also the clinker grinders are driven by a hy-

draulic variable speed transmission; low installation cost made this type of drive advantageous over electrical systems. Two 160,000-kw tandem-compound units were installed. These turbines run at 1,800 rpm with initial steam conditions of 400 lb per sq in. and 730 deg. F. The high pressure cylinder contains 15 stages and the low pressure, 4 double-flow stages. Steam extraction for feed heating occurs at 2 high pressure stages. Performance on the units is 1 per cent better than guaranteed; and since the 320,000-kw addition has been in service, the overall station heat rate has fallen from 15,500 Btu per net kwhr approximately to 13,320.

Bremo Bluff Station of the Virginia Public Service Company has several features indicative of recent trends. The steam generating equipment consists of 2 inclined-tube single-pass boilers, each rated at 200,000 lb per hr evaporation and fired by pulverized coal. The diphenyl compound air-preheating system is used. The unit assembly idea is followed, each boiler serving a 15,000-kw tandem-compound condensing turbine designed for 450-lb pressure and 825 deg F. Steam is bled from 4 stages to rain-type feed water heaters. The units operate at 3,600 rpm. Another feature of the station is its centralized control room midway between the boiler and turbine rooms. Both turbine and control panels are in this room and enable one operator to control a large number of circuits.

Burlington Station of the Public Service (N. J.) Electric & Gas Company is an outstanding example of economies obtained by rehabilitation. An 18,000-3,600-rpm turbine-generator operating at 650 lb per sq in. steam pressure and 850 deg F total temperature is superposed on 3 older units, each of 12,500-kw capacity operating at 190 lb per sq in. and 150 deg F superheat. Thus the machines now form a 55,500-kw 4-cylinder compound unit that has reduced the station heat rate by 37.5 per cent (from 24,000 to 15,000 Btu per kwhr). The new machine is the largest capacity unit at this speed in existence.

V—Oil and Gas Power

Several progressive features are evidenced in the Diesel engine field, such as reduction in weight, use of trunk pistons of large diameter, and increased speed. The increased use of alloy steels is noticeable, also the discontinuance of air injection in favor of mechanical injection. The trend in small plants is largely to the use of the single-acting 2-cycle engine.

The City of Vernon (Calif.) Power Plant will contain 5 7,000-hp double-acting 2-cycle engines and will form the world's largest Diesel-electric power plant. Each engine has 8 cylinders 24 in. by 36 in., runs at 167 rpm, and will drive a 5,000-kw generator.

The Lamoka (N. Y.) combination gas-electric hydroelectric and pumped-storage plant of the Lamoka Power Corporation is unique. The installation consists of a 2,000-hp vertical-shaft hydraulic turbine in operation, and a 7,500-hp turbine under construction. The turbines operate under a net head of 385 ft. One vertical 1,200-hp 6-cylinder 4-cycle gas engine drives an 800-kw a-c generator, and each of 3 1,800-hp engines drives a 1,250-kw generator. Each 1,800-hp unit consists of 2 6-cylinder engines with the generator and flywheel between. These engines are the largest of their kind in this country. During off-peak periods, the gas engine driven generators supply power to pump water into the hydro-plant reservoir by means of one 8,000-gpm and 2 16,000-gpm motor-driven pumps. Natural gas is brought from wells 1,750 ft under the land owned by the power company; it is probable that this is the only combination gas and water power plant using these 2 resources from the same land.

VI—Foreign Steam Plant Developments

There have been no pronounced developments in power generation abroad since 1931, with the exception of the building of the "grid" scheme of transmission in Great Britain. This ideal scheme calls for a few new large, efficient power plants at favorable locations feeding into some 3,000 miles of transmission system, tying all plants together. All load dispatching will be done at a central point in London. The transmission voltage is either 132, 66, or 33 kv. Substations will tap the transmission grid to supply communities with power. The plan requires the abandonment of many small and inefficient plants.

Present English practice seems to favor use of steam at 600 lb and about 850 deg F. In Europe, pressures range from the moderate up to the critical pressure of 3,200 lb, which has been employed in one unit at Langerbrugge, with several installations between 1,200 and 1,800 lb. With few exceptions 850 deg F is the limiting temperature.

The report of the Electricity Commission of Great Britain last year shows several installations having a thermal efficiency of from 22 to 24 per cent obtained with moderate pressures not exceeding 650 lb, and fairly high temperatures. These efficiencies are all being obtained with English coal having a considerably lower Btu value than the coal generally used in the United States.

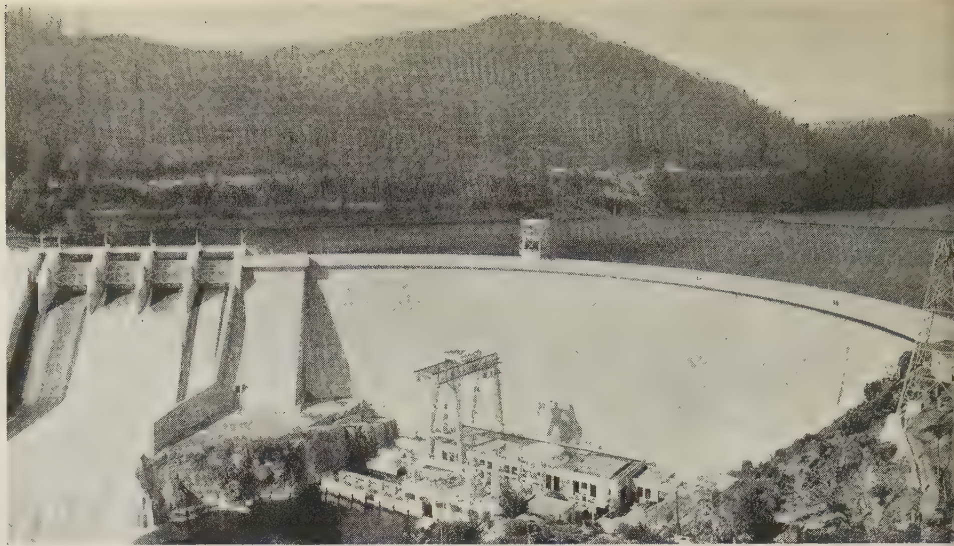
There has been a decided trend toward the use of larger turbine units, capacities ranging up to 100,000 kw with 50,000 kw appearing to be the popular size. Manufacturers are prepared to build 3,000-rpm 50-cycle machines in the larger sizes, and there is one unit of 80,000-kva capacity built for this speed.

The use of larger boiler units increases, and many units are in operation with a steaming capacity of from 200,000 to 300,000 lb per hour. Although furnace sizes also have been stepped up, they still average a little smaller per unit of boiler capacity than those of the latest American practice. The use of water walls is increasing.

Practice in fuel burning equipment shows a tendency to favor stokers over powdered fuel. The forced-draft chain-grate stoker is very popular in England probably because the quality of the fuel used is quite favorable to the use of the chain grate.

The change in trend from powdered coal to stokers seems to be explained by 2 reasons: the lower initial cost of the stoker, and the lesser difficulty in taking care of the kind of dirt in the flue gases from the stokers.

Fly ash removal has been given much attention. An enormous amount of work has been done in developing centrifugal and wet types of eliminators and electrostatic precipitators. German engineers seem to favor the latter type, while in England many stoker fired plants are getting good results with centrifugal and dry type separators. This is much more important abroad than it is in the United States because the average ash content of the fuel is much greater.



Ariel dam and power house of the Inland Power & Light Company on the Lewis River, Wash. This plant is said to contain the largest overhung generator with revolving field installed to date; it is rated 56,200 kva, 120 rpm

English practice favors the straight tube boiler although the bent tube Stirling boiler also is used. In Europe, however, the proportion of bent tube boilers is much larger and they are of a wide variety. Several interesting and radical designs of boilers have been developed which are in commercial operation. The urge for this development work apparently is a desire to use much higher steam pressure without materially increasing the cost of the boiler unit.

The use of heat accumulators such as the installation in Charlottenburg, Germany, apparently has made little progress. While this installation successfully handles peaks of certain duration, apparently the initial cost, space required, and low efficiency are factors that are retarding this development.

There is nothing especially new in the switch house. The general practice in England, largely because of the Board of Trade Rules, is the use of "iron-clad" switchgear placed indoors. European practice is similar to American. With few exceptions, no foreign switch house has to handle as large quantities of energy as do many American stations.

VII—Developments in Hydroelectric Practice

Progress in hydroelectric practice during the past 2 years was foretold to a large extent in the 1931 report of this committee, when the impending developments in the use of the Kaplan turbine in this country were discussed. Other than this significant step there does not appear to be any distinctive innovations of major importance in the designs of the hydroelectric projects placed in operation during the past 2 years. The probable future trend, if any, with regard to the type of propeller turbine that may be preferred for low head plants, however, is not yet clear. The Kaplan, or automatically adjusted-blade turbine, was installed in the Safe Harbor Plant on the Susquehanna River in Pennsylvania; manually adjusted-blade turbines in the Rock Island Plant on the Columbia River in Washington; and fixed-blade turbines in the Chats Falls Plant on the Ottawa River in Canada. These plants are typical examples of the most recent use of propeller turbines for low head developments. A very interesting high head development was placed in service on the Mokelumne River in California. The Ariel Plant on the Lewis River, Washington, and the Wyman Dam development on the Kennebec River, Maine, were representative of medium head designs and displayed novel ideas in building and superstructure designs.

Interest in cavitation investigations in this country has continued largely as the result of the increasing use of the propeller turbine in low head plants. The first cavitation research laboratory in the United States was recently opened at the Massachusetts Institute of Technology, Cambridge, and there are now several commercial and institutional laboratories equipped for making cavitation tests on model runners. Testing of models of all important structures comprising a hydroelectric development is now accepted practice, and is well exemplified by the extensive model studies made for the Boulder Dam on the Colorado River. The European practice of using multiple current meters distributed over the intake area for the field testing of hydraulic turbines, was introduced in the United States at the Safe Harbor plant, where the short length of intake passage was believed to render the commonly used methods of water measurement of doubtful value.

The number of pumped storage developments on this continent is small compared with those in Europe, but the possibility of regenerative pumping at the Safe Harbor plant by means of the dual use of the same unit as a turbine and a pump has been

investigated recently. Turbine manufacturers have developed runners suitable for such dual use, and the electrical problems incident to reverse operation at either a similar speed or a dual speed appear possible of ready solution. The limited practice heretofore in this country has been to install a motor driven pump entirely separate from the turbine-generator, although both pump and turbine are connected to the same penstock. The arrangement commonly found in Europe consists of a single electrical element used either as a generator or motor, with a permanently connected turbine on one side and a clutch connected pump on the other.

Discussion of the economics of hydroelectric projects during the past 2 years has been focused on: the determination of the cost characteristics of different types of developments; the relative economy of water power as compared with steam power; the influence that the incremental cost of hydroelectric capacity has upon the size of development; and the peak substitutional value of water power as compared with steam power on the available load curve. The latter 2 factors are of particular importance in the consideration of pumped storage and regenerative installations.

Development of the Mokelumne River in California having a drainage area of 365 square miles, over a gross static head of 5,100 ft by means of 4 plants in series on the flow line without appreciable intervening storage, may be the last high head development for some time on the Pacific Coast. The maximum flow used, 650 cfs, is 80 per cent of the average yearly stream flow, which is regulated almost completely by storage reservoirs having a volumetric capacity equal to $^1/_3$ of the volume of run-off. There are 3 impulse installations operating at gross heads of 2,089, 1,265, and 1,219 ft; and 2 Francis wheel installations for heads of 285 and 245 ft. One of the 5 main dams is the largest rock-fill dam in the world, having a height of 328 ft and a crest length of 1,300 ft. The peak capacity of the plant is 144,000 kw and will be used about 80 per cent of the time.

The Rock Island plant on the Columbia River is the first major low-head run-of-river development on the Pacific Coast and also the first step in the development of the hydroelectric possibilities of the Columbia River. The drainage area above the plant is 90,000 square miles; maximum and minimum recorded flows have been 740,000 and 21,000 cfs, respectively, and the mean flow is 121,000 cfs. The head for the initial installation of 4 21,000-hp units is 32 ft; it will be increased to 48 ft with the addition of more units, of which there ultimately will be 12. Initial full draft water requirements are about 75 per cent of the minimum steady flow, and about 135 per cent of the lowest recorded flow. Because of the low- and varying-head conditions, manually-adjusted-blade propeller wheels were installed; these have a diameter of 223 in. and are the largest propeller wheels on this continent. The plant operates at a capacity use factor of about 90 per cent, which, in comparison with the run-of-river plants in the eastern section of the United States, represents a relatively small capacity installation with respect to the minimum flow capacity.

The Chats Falls plant on the Ottawa River, Canada, is a low head development 53 ft, showing a somewhat greater ratio of installed capacity to regulated flow capacity. The drainage area above the plant is 34,000 square miles, but because of the presence of numerous lakes the minimum dependable flow is now 22,000 cfs. The 8 28,000-hp fixed-blade propeller units require a full draft equal to 2 times the minimum flow. This plant serves a large system that derives its entire supply of electric power from hydroelectric sources.

Tiger Creek plant of the Pacific Gas & Electric Company on the Mokelumne River, Calif. This plant contains 2 double overhung impulse units operating on a head of 1,190 ft and driving 2 generators each rated 30,000 kva

The Safe Harbor plant on the Susquehanna River is notable for having the highest powered propeller turbines in the world, the units being rated at 42,500 hp under a head of 55 ft. The full draft requirement of the plant initially is about 12 times the minimum regulated flow; the yearly use factor will approximate 50 per cent. The initial installation consists of 6 units, with head-works structures for 6 additional units. The hydraulic and electrical design anticipates the dual use of the units for generation and regenerative pumping; the plant will be the first low head development planned for such operation, which is readily accomplished because the Safe Harbor plant discharges directly into the pond formed by the Holtwood dam 8 miles

farther down the river. The electrical layout in the plant provides for: 3-phase 60-cycle, and single-phase 25-cycle generation; 60-cycle low voltage buses; and control of transformers placed above the bus galleries for stepping up to 69 and 230 kv for transmission. The 25-cycle generators will be the largest single phase waterwheel units in the country, having a rating of 37,500 kva at 80 per cent power factor. High voltage switch yards for the control of outgoing 60- and 25-cycle transmission lines will be placed on shore adjacent to the power house. Outdoor frequency changers rated at 25,000 kw, 80 per cent power factor, will be installed below the bulkhead connecting the power house with the shore.

The Ariel and Wyman Dam plants exhibit an interesting treatment of superstructure design, which in both plants consists of a low roof with removable hatches over the generators. Outdoor 2-leg gantry cranes serve the generator areas; that at the Ariel plant is the largest outdoor power house crane yet built, having a span of 67 ft, a lift of 80 ft above crane rails, and a capacity of 350 tons. The Ariel plant is notable also for having the largest overhung generator with revolving field installed to date; it is rated 56,250 kva at 80 per cent power factor, 120 rpm. Other novel features of the Ariel plant are the location of a part of the power house upon a concrete arch spanning a deep gut in the foundation rock, and the location of the control room in an adjacent but separate building. The drainage area above the Ariel plant is 733 square miles. One 55,000-hp 170-ft-head unit has been installed initially; the complete plant will contain 4 units with the expectation of using seasonal storage for low use-factor operation. The Wyman Dam plant has an initial installation of two 34,000-hp 135-ft-head units, with provision for a third unit in the future. The use factor of this plant will be of the order of 45 per cent.

Records for maximum size and extreme conditions of installation of propeller turbines continue to remain with European plants. Among the more notable are the following Kaplan installations:

Plant	Horsepower	Head, Ft	Runner Diam, In.	Discharge, Cfs	Speed, Rpm
Vargon, Sweden	15,000	14	315	11,090	46.9
Swir, Russia	37,500	36.1	292	10,240	75
Shannon, Ireland	33,000	106*	161	3,040	167

* Head initially is 82.25 ft.

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34. Electrical Design Features of Waukegan Station, E. C. Williams. Trans. A.I.E.E., v. 51, Sept. 1932, p. 644.

35. Electrically Driven Auxiliaries for Steam Power Stations, L. W. Smith. Trans. A.I.E.E., v. 51, June 1932, p. 337.

36. Experience at Station "A" With 1,250-Lb Steam, R. C. Powell. *Elec. World*, v. 98, Sept. 26, 1931, p. 544–7.

37. Glenwood Station, More Power for Long Island. *Pwr. Plant Engg.*, v. 35, Oct. 15, 1931, p. 1006–15.

*Fuels and steam power division.

38. Harding Street Station at Indianapolis. *Pwr. Plant Engg.*, v. 36, Feb. 15, 1932, p. 152–3.

39. Higher Steam Pressures and Temperatures—A Challenge to Engineers, M. D. Engle and I. E. Moultrop. *Elec. Engg.*, v. 52, Jan. 1933, p. 3.

40. High-Pressure Boiler and Turbine Operation at Northeast Station, J. A. Keeth. *Trans.* A.S.M.E., FSP v. 54, Aug. 30, 1932, p. 161.

41. Hudson Avenue Station, Brooklyn; 45,000 Kw Served by Boilers in Space Originally Serving 12,000 Kw. *Power*, May 31, 1932.

42. Improvements at the Burlington Generating Station, W. L. Cisler and W. P. Gavit. A.I.E.E. Paper No. 33–76 (scheduled for publication in A.I.E.E. Trans., v. 52, 1933).

43. Improvements in Missouri-Kansas Coals and Their Burning Equipment, E. L. McDonald. *Trans.* A.S.M.E., FSP v. 54, May 30, 1932, p. 91.

44. Lakeside a Decade of Progress. *Pwr. Plant Engg.*, v. 35, Aug. 15, 1931, p. 830–7.

45. Lincoln's New Generating Station Bleeds Steam for District Heating and Process. *Power*, v. 75, Dec. 29, 1931, p. 885–90.

46. Once-Through Series Boiler for 1,500 to 5,000 Lb Pressure, H. J. Kerr. *Trans.* A.S.M.E., FSP v. 54, Nov. 15, 1932, p. RP-54-1a.

47. Operating Engineering Problems, A. E. Silver. N.E.L.A. *Bulletin*, Aug. 1932.

48. Operating Experience, Deepwater Station, K. M. Irwin. *Trans.* A.S.M.E., FSP v. 53, Oct. 1, 1933, p. 285.

49. Operating Experience With 1,800-Lb Steam at Plant Carey, H. P. Stephenson. *Power*, v. 77, April 1933, p. 169.

50. Operation of the Holland Station, E. M. Gilbert. *Trans.* A.S.M.E., FSP v. 53, Oct. 1, 1933, p. 275.

51. Performance of Modern Steam-Generating Units, C. F. Hirshfeld and G. U. Moran. *Trans.* A.S.M.E., FSP v. 54, Nov. 15, 1932, p. 205.

52. Program Load Control Improves Steam Economy, A. P. Hayward and R. Decamp. *Power*, Nov. 1932.

53. Progress in Fuels. *Trans.* A.S.M.E., FSP v. 55, March 15, 1933, p. 1

54. Progress in Steam-Power Engineering. *Trans.* A.S.M.E., FSP v. 55, March 15, 1933, p. 7.

55. Public Service Company's 1,400-Lb Plant at San Antonio, Texas. *Pwr. Plant Engg.*, v. 35, June 15, 1931, p. 664–6.

56. Pulverization and Boiler Performance, E. H. Tenney. *Trans.* A.S.M.E., FSP v. 54, Jan. 15, 1932, p. 55.

57. Radiant-Superheater Developments, M. K. Drewry. *Trans.* A.S.M.E., FSP v. 54, no. 21, Nov. 15, 1932, p. 181.

58. Single Pass Boiler and Its Economic Field, Otto DeLorenzi. *Pwr. Plant Engg.*, Aug. 15, 1931.

59. Single Pass Boiler at Duluth, Minn., A. H. Krauss. *Combustion*, March 1932.

60. Slag Tap Furnaces, A. L. Baker. *Trans.* A.S.M.E., FSP v. 54, Jan. 15, 1932, p. 1.

61. South Amboy Plant of the Jersey Central Power and Light Company, R. C. Roe and F. P. Mailler. *Trans.* A.S.M.E., FSP v. 53, Oct. 1, 1933, p. 335.

62. State Line Station—Chicago. *Engg.*, Feb. 12, 1932, March 4, March 18, and April 1932.

63. Steam-Driven Auxiliaries for Power Plants, W. Poole Dryer. Trans. A.I.E.E., v. 51, June 1932, p. 331.

64. Steam Power Plant Practice, A. G. Christie. *Mech. Engg.*, v. 54, Sept. 1932, p. 635–40.

65. Steam-Turbine-Plant Practice in the United States, Vern E. Alden and W. H. Balcke. *Trans.* A.S.M.E., FSP v. 55, March 15, 1933, p. 9.

66. Steam Turbines. N.E.L.A. *Proc.*, v. 89, July 1932, p. 996–1033.

67. 375,000 Kva From One Generating Unit, C. M. Laffoon. *Elec. Journal*, v. 29, April 1932, p. 165–7.

68. Trend in Boiler Development Toward Simplicity, R. C. Roe. *Pwr Plant Engg.*, Dec. 15, 1931.

69. Trends in the Design and Operation of Large Underfeed Stokers. *Power*, March 22, 1932.

70. Two and a Half Years Experience With 1,350 Lb Steam Plant, J. A. Powell and G. T. Dempsey. *Elec. World*, Nov. 26, 1932.

71. Two Tandem Units Add 320,000 Kw to Hudson Avenue Station of Brooklyn Edison Company. *Power*, v. 75, May 31, 1932, p. 815–19.

Steam-Electric Developments—Foreign

72. Benson and Atmos Boilers. *Engg.*, Sept. 11, 1931.

73. British Practice in Boiler Design, J. Bruce. *Engg. and Boiler House Rev.*, April 1931.

74. British Practice in Steam-Turbine Design, F. W. Gardner. *Trans.* A.S.M.E., FSP v. 55, March 15, 1933, p. 37.

75. Development in Steam-Plant Practice, F. Nicholls. *Journal*, Institution of Elec. Engrs., v. 70, Dec. 1931, p. 69–72.

76. Foreign Developments. N.E.L.A. *Proc.*, v. 89, 1932, p. 970.

77. High Pressure Boiler Design in Europe, C. J. Webb. *Pwr. Plant Engg.*, April 1, 1932.

78. Modern Super-Pressure Steam Operation in Germany, D. Brownlie. *Steam Engg.*, Jan. 1932.

79. St. Dennis Heralds New Era in French Steam-Plant Practice, R. H. Andrews. *Power*, v. 74, Dec. 29, 1931, p. 921–4.

Hydroelectric Developments—American

80. Ariel Hydro Development, A. C. Clogher and W. S. Merrill. *Elec. World*, March 5, 1932, p. 442.

81. Beauharnois Development of the St. Lawrence River (Canada), W. S. Lee. Elec. Engg., v. 52, June 1933, p. 377–84.

82. Eagle-Pass Hydroelectric Development, L. F. Harza and J. S. Bowman. *Pwr. Plant Engg.*, v. 36, Aug. 1, 1932, p. 582–6.

83. Economic Aspects of Water Power, F. A. Allner. Trans. A.I.E.E., v. 52, March 1933, p. 156.

84. Gas Power Supplements Hydro in Pumped-Storage Plant. *Power*, v. 76, Aug. 1932, p. 76–78.

85. Hardy Dam Provides 40,000 Hp for Michigan Peak Load, E. M. Burd. *Pwr. Plant Engg.*, v. 36, March 1, 1932, p. 194–8.

86. Hydraulic-Turbine Governors and Frequency Control. N.E.L.A. *Proc.*, v. 88, 1932, p. 543–72.

87. Hydroelectric Developments and the Correlation of Hydro and Steam Power, F. A. Allner. *Mech. Engg.*, v. 54, Oct. 1932, p. 595–9.

88. Hydroelectric Developments in Canada, T. H. Hogg. *Mech. Engg.*, v. 54, Oct. 1932, p. 547–52.

89. Impulse Wheels Develop 86 Per Cent Efficiency at Tiger Creek Plant, C. V. Foulds. *Power*, v. 75, March 29, 1932, p. 461–5.

90. Low-Head Hydroelectric Developments, A. V. Karpov. Trans. A.I.E.E., v. 52, March 1933, p. 202.

91. Making Water Measurements With Current Meters, S. J. Bitterli. *Power*, v. 75, Jan. 19, 1932, p. 102–04.

92. Mokelumne River Development of the Pacific Gas and Electric Company, E. A. Crellin. Trans. A.I.E.E., v. 51, March 1932, p. 28.

93. Osage Hydroelectric Development, C. C. Dodge. *Elec. Journal*, v. 29, Feb. 1932, p. 57–60.

94. Power Development at Chats Falls. *Canadian Engr.*, v. 61, Oct. 20, 1931, p. 9–11.

95. Power Storage by Pumping. *Pwr. Plant Engg.*, April 1, 1932.

96. Pumped Storage Hydroelectric Plants for Regeneration, L. F. Harza. *Pwr. Plant Engg.*, v. 35, June 1, 1931, p. 597–601.

97. Safe Harbor Kaplan Turbines, L. M. Davis and G. W. Spaulding. Trans. A.I.E.E., v. 52, March 1933, p. 220.

98. Safe Harbor Project, N. B. Higgins. Trans. A.I.E.E., v. 52, March 1933, p. 169.

99. Segregation of Hydroelectric Power Costs, W. S. McCrea, Jr. Trans. A.I.E.E., v. 52, March 1933, p. 1.

100. Tacoma Completes Second Cushman Plant, V. Gongwer. *Civil Engg.*, v. 1, Sept. 1931, p. 1106–10.

101. White-Rapids Automatic Hydroelectric Station, H. W. Gochnauer. *G. E. Rev.*, v. 34, Sept. 1931, p. 507–11.

102. Wyman-Dam Development, Central Maine Power Company, H. K. Fairbanks. *Pwr. Plant Engg.*, v. 36, July 1, 1932, p. 518–22.

Hydroelectric Developments—Foreign

103. Bringhausen, Pumped-Storage Hydro Plant Has Highest Head. *Power*, v. 73, May 19, 1931, p. 782.

104. Dogern on the Rhine, A. J. Luchinger. *Pwr. Plant Engg.*, v. 36, Nov. 1932, p. 774–6.

105. Herdecke, the Largest Pumped-Storage Hydroelectric Plant, W. Netoliczka. *Power*, v. 75, Feb. 2, 1932, p. 160–3.

106. Hydraulic Practice in Europe, W. R. Angus. *Trans.* A.S.M.E., †HYD v. 54, Nov. 30, 1932, p. 123.

107. Modernizing Trollhattan, Sweden's Largest Hydro Plant, G. Willock. *Power*, v. 75, June 21, 1932, p. 518–20.

108. Research Institute for Hydraulic Engineering and Water Power, Hunter Rouse. *Trans.* A.S.M.E., HYD v. 54, May 15, 1932, p. 27.

109. Ryburg-Schwopstadt Hydroelectric Power Station. *Engg.*, v. 134, Aug. 5, 1932, p. 152–3.

110. Waggital Pumped-Storage Hydroelectric Scheme. *Engg.*, v. 132, Sept. 4, 1931, p. 292–4.

†Hydraulic division.

News
Of Institute and Related Activities

Summer Convention Starts Successfully

The 49th annual summer convention of the A.I.E.E. held in Chicago, Ill., during Engineers' Week, June 26–30, 1933, was under way as this issue went to press, and will be reported in detail in the August issue of ELECTRICAL ENGINEERING.

In the present issue, however, there are included elsewhere reports of some of the features of the opening day, including the annual meeting with announcement of the election of officers, award of Institute prizes, presentation of Lamme Medal, announcement of the election of 6 Honorary Members, and the annual presidential address delivered by President Charlesworth.

The first day's registration was 427, compared with a registration of 422 on the first day of the 1932 summer convention held at Cleveland, Ohio, and of 382 for the 1931 summer convention held at Asheville, N. C.

A change in the technical program which was made after the announcement was printed was the withdrawing of the address "Recent Developments in Sound Measurements," by H. B. Marvin, General Electric Company, from the instruments and measurements session on June 27, 1933. In place of this address the following paper was presented:

REPORT ON THE STATUS OF THE WORK ON NOISE MEASUREMENT OF THE A.S.A. SECTIONAL COMMITTEE ON ACOUSTICAL MEASUREMENTS AND TERMINOLOGY, Dr. Harvey Fletcher, *chairman*, subcommittee on noise measurement.

Lamme Gold Medal for 1932 Presented

THE Lamme Gold Medal was formally presented to EDWARD WESTON (A'84, M'84, HM'33, Member for Life, and past-president) chairman of the board, Weston Electrical Instrument Corporation, Newark, N. J., on June 26, 1933 at the annual business meeting of the A.I.E.E. held during the summer convention at Chicago, Ill. This medal was established by provision of the will of Benjamin Garver Lamme (deceased July 8, 1924) for the encouragement and recognition of "meritorious achievement in the development of electrical apparatus or machinery."

Previous A.I.E.E. awards of the Lamme Medal have been made to A. B. FIELD (A'03, F'13) consulting engineer, Manchester, England, 1928; R. E. HELLMUND (A'05, F'13) chief engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., 1929; W. J. FOSTER (A'07, F'16) consulting engineer, retired, General Electric Company, Schenectady, N. Y., 1930; and GIUSEPPE FACCIOLI (A'04, F'12) retired, associate manager of the Pittsfield (Mass.) Works of the General Electric Company, 1931.

By Mr. Lamme's will, 2 other similar bequests were made, one to Ohio State University, and one to the Society for the Promotion of Engineering Education. The Lamme Medal of Ohio State University, to be awarded to a graduate of one of the technical departments for meritorious achievement in engineering of the technical

arts, was presented for 1933 to N. W. STORER (A'95, M'03, F'13) consulting railway engineer of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa. Brief biographical sketches of Doctor Weston and Mr. Storer are given in the personal columns of this issue.

Additional Awards for 1932 Institute Papers

In addition to the national and District prizes for papers presented before the Institute during the calendar year 1932, as announced in ELECTRICAL ENGINEERING for June 1933, p. 424–5, announcement now has been made of the award of prizes for District No. 8. These awards are:

Prize for best paper awarded to Joseph S. Carroll (A'24) and Bradley Cozzens (A'28) for their paper "Corona Loss Measurements for the Design of Transmission Lines to Operate at Voltages Between 220 Kv and 330 Kv," presented at the Pacific Coast Convention, Vancouver, B. C., August 30–September 2, 1932.

Prize for Branch paper awarded to William J. McLeod (A'33) for his paper "The Precise Electrical Measurement of Short-Time Intervals," presented at a joint meeting of the San Francisco Section and the University of Santa Clara, University of California and Stanford University Branches on April 15, 1932.

Outline of Minutes of 1933 Annual Meeting

With President Charlesworth presiding, the annual meeting of the American Institute of Electrical Engineers was held at the Edgewater Beach Hotel, Chicago, Ill., as the opening session of the annual summer convention, June 26, 1933.

The annual report of the board of directors was presented in abstract by H. H. Henline, national secretary. Printed copies were distributed to members in attendance and are available to any member upon application to Institute headquarters, New York, N. Y. The report, which constitutes a résumé of the activities of the Institute during the fiscal year which ended April 30, 1933, shows a total membership on that date of 17,019. In addition to the 3 national conventions and 2 District meetings, 1,524 meetings were held during the year by the local organizations of the Institute in the principal cities and educational institutions in the United States, Canada, and Mexico. The report will appear in full in the quarterly TRANSACTIONS of the Institute.

The report of the committee of tellers on the election of officers of the Institute was presented, and in accordance therewith President Charlesworth declared the election of the following members, taking office August 1, 1933:

President: John B. Whitehead, dean of the faculty of engineering, The Johns Hopkins University, Baltimore, Md.

Vice-Presidents:

A. M. Wilson, professor of electrical engineering, University of Cincinnati, Ohio.

F. M. Craft, chief engineer, Southern Bell Telephone & Telegraph Company, Atlanta, Ga.

R. B. Bonney, educational director, Mountain States Telephone & Telegraph Company, Denver, Colo.

R. W. Sorensen, senior professor of electrical engineering, California Institute of Technology, Pasadena, Calif.

A. H. Hull, station engineer, Hydro-Electric Power Commission of Ontario, Toronto, Ont.

Directors:

P. B. Juhnke, chief load dispatcher, Commonwealth Edison Company, Chicago, Ill.

Everett S. Lee, engineer in charge, General Engineering Laboratory, General Electric Company, Schenectady, N. Y.

L. W. W. Morrow, editor, *Electrical World*, New York, N. Y.

National Treasurer:

W. I. Slichter, professor of electrical engineering, Columbia University, New York, N. Y.

The board of directors for the next administrative year, beginning August 1, 1933, will consist of these newly elected officers, together with the following hold-over officers: H. P. Charlesworth (retiring president), New York, N. Y.; C. E. Skinner, Wilkinsburg, Pa.; K. A. Auty, Chicago, Ill., C. R. Higson, Salt Lake City, Utah; J. Allen Johnson, Buffalo, N. Y.; E. B. Meyer, Newark, N. J.; Stanley Stokes,

St. Louis, Mo.; L. W. Chubb, East Pittsburgh, Pa.; A. B. Cooper, Toronto, Ont.; B. D. Hull, Dallas, Tex.; A. E. Knowlton, New York, N. Y.; G. A. Kositzky, Cleveland, Ohio; A. H. Lovell, Ann Arbor, Mich.; A. C. Stevens, Schenectady, N. Y.; R. H. Tapscott, New York, N. Y.; H. R. Woodrow, Brooklyn, N. Y.

President Charlesworth then congratulated President-Elect Whitehead upon his election and presented him with the president's badge. Dr. Whitehead responded with a brief address, which was enthusiastically received.

The report of the committee on award of Institute prizes, as published in the June 1933 issue of Electrical Engineering, p. 424–5, was read by W. H. Harrison, chairman of the committee, after which the certificates of award were presented by President Charlesworth.

The Lamme Medal for 1932, which, as announced on p. 282 of the April 1933 issue of Electrical Engineering, had been awarded to Edward Weston (A'84, M'84, HM'33, Member for Life, and past-president), of Montclair, N. J., was presented.

Announcement was made of the election by the board of directors, on May 22, 1933, of the following Honorary Members of the Institute: W. L. R. Emmet, George A. Hamilton, A. E. Kennelly, Robert A. Millikan, E. W. Rice, Jr., Edward Weston; and certificates were presented. Information regarding the careers of these Honorary Members may be found elsewhere in this issue.

The annual presidential address then was delivered by President Charlesworth. (See p. 445–8.)

Adjourned.

(*Signed*) H. H. Henline
National Secretary

Election of Honorary Members Announced

Formal announcement of the election of 6 prominent individuals to honorary membership in the Institute was made at the annual meeting held during the 49th annual summer convention, Chicago, Ill., June 26, 1933. These new honorary members, all elected by unanimous vote of the Institute's board of directors at its meeting of May 22, 1933 are as follows:

W. L. R. Emmett	Robert A. Millikan
George A. Hamilton	E. W. Rice, Jr.
A. E. Kennelly	Edward Weston

As specified by the Institute's constitution, "honorary members may be chosen from among those who have rendered acknowledged eminent service to electrical engineering or its allied sciences." Each member of this distinguished group is more than qualified to meet this requirement. Biographical sketches are presented in the personal columns of this issue.

The grade of Honorary Member is the highest in the Institute, and is held by only 9 other individuals; these are: Andre E. Bondel, Herbert Hoover, Guglielmo Marconi, Michael I. Pupin, Charles F. Scott, Motoji Shibusawa, Frank J. Sprague, Ambrose Swasey, and Elihu Thompson.

New Illumination Fixtures Feature Chicago Exposition

Westinghouse Photo

Looking east across the lagoon from the mainland at the Century of Progress Exposition, Chicago's 1933 World's Fair, a striking picture of the many illumination features is obtained. On Northerly Island, the electrical group appears in the center, with the Federal Building at the left and the Horticultural Building at the right. In the foreground appear 2 of the mushroom lighting units of special design, which illuminate the garden, paths, and secondary roadways without detracting from the mass lighting of the main buildings. These units, about 4 ft high, give the visitor the effect of walking about waist deep in a sea of light free from all glare. The mushroom luminaire consists of a short aluminum standard on which is mounted an inverted cone of translucent micarta, the colors of which vary for different parts of the grounds. Concealed under the cone is a 150-watt clear Mazda lamp in a prismatic refractor, which distributes most of the light approximately 10 deg below the horizontal, giving maximum spread without glare. The light directed by the refracting prisms to the grass and pathways is ordinary clear light, while that transmitted to the eye from the cones is of low intensity in glowing colors. The mushrooms are spaced approximately 80 ft apart.

San Francisco Section Stimulates Student Relations

The San Francisco, Calif., Section of the Institute maintains a Student relations committee for the purpose of developing and fostering contacts between the Section and the Student Branches at the University of Santa Clara, University of California, and Stanford University. To facilitate this the committee membership consists of a faculty member and an alumnus of each of the 3 universities. These men, particularly the faculty members, represent an outpost of the Institute that is in continuous contact with the Students and always accessible to them.

One important phase of the committee's work is in retaining in the Institute those students who are leaving college. During the past year the committee contacted all students whose term of student membership expired, and brought to their attention the desirability of transferring to Associate membership at once and so avoiding the usual entrance fee.

In order to develop among the students a greater interest in the Section activities the Section executive committee has during the past year paid the dinner check of one Student from each Branch at each meeting, and a Section member serves as host at the dinner for the Students from each Branch. There have normally been about 6 Students attending the dinners, and the plan appears to have created a very favorable impression.

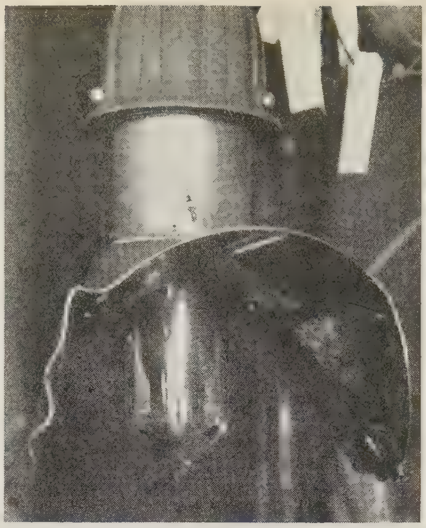
Sodium Vapor Highway Light Demonstrated

The characteristic orange-yellow glow of sodium vapor provides night illumination for a highway near Schenectady, N. Y., where 22 sodium vapor lighting units have been placed, under the joint sponsorship of the General Electric Company and the New York Power and Light Corporation. This half mile of highway is stated to be the

first to be so illuminated in the United States.

The monochromatic light of sodium falls in a region near the maximum sensitivity of the eye, and although it has disadvantages in interior illumination where color discrimination is important, this light is valuable in highway lighting as it is believed to be especially useful in revealing the details of objects at low levels of illumination. Further, these lamps can be manufactured with 2 to 3 times the efficiency of the tungsten filament lamp.

The lamps are equipped with a special type of reflector designed to put the light on the road rather than to distribute it in all directions. The lamp itself is a gaseous discharge device, mounted within a "thermos bottle" to conserve heat and maintain the sodium at about 480 deg F. It is 7 in. long and less than 3 in. in diam, and fits closely within the "thermos" globe. The arc current is carried through the lamp by the gas itself instead of by a filament. The lamp wattage is about 80 to 90 watts and the light output about 4,000 lumens, equivalent to the 400-cp Mazda lamp which consumes 215 watts.



Sodium vapor street lighting unit, not lighted. View taken in the direction of looking down the highway. The dissimilar sides of the reflector allow the unit to be placed to one side of the center of the highway

Summarized Review of Some Schenectady Meeting Discussions

PRINCIPAL discussions of the Schenectady meeting papers are summarized herewith. The papers to which these discussions refer were abstracted in ELECTRICAL ENGINEERING for May 1933, p. 341–2, excepting the papers given more complete treatment in this issue or the previous issue.

Only discussion submitted in writing in accordance with governing A.I.E.E. rules is summarized. Complete discussion, together with all approved papers, will be published in the TRANSACTIONS.

Electrical Characteristics of Impregnated Cable Papers

R. Reiter (Cambridge, Mass.) commented on the slopes of the power loss voltage gradient characteristics which reached a maximum in the range of temperature variation employed. He pointed out that the findings of other investigators were similar and he believed it is possible that, as in the case of the turbine-alternator set, critical points exist which must be avoided by the cable designer in choosing and using cable materials, and in specifying the proper operating range of the finished cable.

Another discusser, Eric A. Walker (Cambridge, Mass.) presented curves and analyzed the relationship between the electrical characteristics of cables and the frequency. Rubber insulated cables also were tested which brought out very different characteristics from those obtained on the paper insulated cable.

J. B. Whitehead (Baltimore, Md.) in his discussion accounted for, in terms of the theory of dielectric absorption, most of the behavior shown by the authors for impregnated paper. Under this theory power loss increases as the square of the voltage gradient. At higher temperatures the increase in the conductivity of the oil causes a more rapid rise with voltage. At low temperatures power factor is independent of the voltage gradient and may either rise or fall at higher temperatures, depending upon the initial conductivity or ionic content of the oil. Power loss is proportional to frequency but also proportional to power factor and the latter may either rise or fall with frequency. Consequently, the power frequency relationship is not simple. In the discusser's opinion the power factor-frequency curve is not a hyperbola, but the curves as shown in this paper, if extended to lower frequencies, would pass through a maximum decreasing to zero at zero frequency. The discusser referred to a number of variations in the shape of the loss temperature curve of impregnated paper, as affected by the characteristics of the oil which were shown in his paper "The Dielectric Losses in Impregnated Paper" presented at the 1933 winter convention of the Institute.

Loss Characteristics of Silicon Steel at 60 Cycles With D-C Excitation

B. M. Smith (Schenectady, N. Y.) in his discussion of this subject cited that hysteresis loss decreases with superposed direct current. This fact in the past has given engineers encouragement to believe that it would be possible to obtain lower core loss in power transformers by this means. The data given in the paper, however, show that although the hysteresis loss is decreased, there is a proportionately greater increase in the exciting current, which would indicate that the application of direct current could not be used for decreasing transformer losses.

Another discusser, A. L. Gokhale (Schenectady, N. Y.), raised the question from the physicist's point of view as to why we know so little about magnetism, although we know comparatively so much more about electricity. He summarized the several theories and conceptions of magnetic phenomena developed from the time of Weber in 1852. He emphasized that the conception of B in Weber's theory led to the conclusion that permeability is a nondimensional quantity. He pointed out that the Rucker theory of "suppressed dimensions" rapidly gained in popularity and that it is now accepted by a majority of scientists. The acceptance of one necessarily involves a rejection of the other. In this way acceptance of the latter theory may have caused to be rejected unconsciously a very valuable analytical instrument for magnetic research. The discusser believed that until the question as to whether permeability is a dimensional or a non-dimensional quantity is answered with convincing evidence in support of the answer there did not seem to be a likelihood of a rational explanation of the magnetic phenomena.

C. MacMillan (Schenectady, N. Y.) believed that the data given in this paper should prove valuable to designers of various types of electrical apparatus. He pointed out that the cases to which the results are immediately applicable are confined to those in which the superposed fields are in line with a common axis. However the data also should afford assistance in cases involving more complex conditions, and field axes which are not necessarily in alignment, such as in the magnetic circuits of induction motors.

Design of Resistance Welder Transformers

In connection with this subject, W. C. Hutchins (Schenectady, N. Y.) related the rapid development of thyratron control to resistance welding and he described its applications. Three main reasons why the heating of the welder transformer might be greater if a non-synchronous contactor is used than when thyratron control is used were given by the discusser. He also referred to the imposition of power factor penalties in certain localities for the objectionable features or characteristics of the resistance welding load which he explained may be overcome by the application of motor generator sets.

S. T. Maunder (Pittsfield, Mass.) in his discussion of this subject wished to emphasize for the benefit of the industry at large that the requirements for secondary voltage and capacity are usually much higher than anticipated. He explained that difficulty is usually encountered by underestimation of requirements at the weld, larger current flow than was presupposed and too large a drop in the terminals or lines to the weld. The drop sometimes is mainly due to excessive reactance in the lines, which is often nearly 100 per cent.

Radio Aids to Air Navigation

W. H. Thompson (Lt. Commander, U.S.N.) in his discussion emphasized the

need for intelligent operation of all scientific equipment in the light of its capabilities, for defects in such equipment may produce errors at possibly rare intervals which are difficult to detect. To obtain the correct bearing with the aid of the radio direction finder he called attention to the need for applied corrections to compensate for the disturbance caused by the structure of the plane. He also referred to propagation phenomena such as "night effect" which may produce errors or make bearings difficult to obtain. He also told of a case where the gradual failure of a capacitor in a beacon transmitter caused a shift in bearing.

J. H. Dellinger (Washington, D. C.) gave a summary of the development of a system of radio aids for the blind landings of airplanes as developed by the Bureau of Standards serving as the research division of the aeronautics branch, U.S. department of commerce. In the system developed lateral position is given by a runway localizing beacon, longitudinal position by marker beacons and vertical position by a landing beam. The longitudinal position is transmitted in special signals to the pilot's head-phones by 2 marker beacons, one as he passes over a point 2,000 ft before the edge of the field is reached and the other is heard at the edge of the field. The indications from the runway localizing beacon and the landing beam are received on a single instrument with 2 pointers. One pointer is vertical and tells him his position laterally and the other is horizontal and tells him his position in the vertical plane. By so operating the airplane controls as to keep the 2 pointers crossed at right angles, the pilot keeps the plane on the proper path for landing. When the second marker-beacon signal is heard the pilot levels off and lands.

This subject was also discussed by P. V. H. Weems (Lt. Commander, U.S.N.) who briefly analyzed the several methods of air navigation available. He was optimistic in regard to radio navigation particularly in view of the fact that radio is a new art and so much has been accomplished in such a short time. The discusser had seen 2 impressive demonstrations of the automatic steering control with automatic radio drift correction described in this paper and in his opinion it was difficult to overestimate the value of this development.

Air Conditioning of Homes

W. W. Shaver (Corning, N. Y.) in his discussion of this subject referred to the large cooling load required, as indicated in the paper, due to the sun's radiation through the windows. Ordinary window glass transmits about 87 per cent of the total energy and 92 per cent of the visible light in the sun's radiation. He suggested the use of special heat resisting heat absorbing glasses which can be made to transmit only from 42 to 20 per cent of the sun's total radiation and from 78 to 45 per cent of the visible light. Experiments are now being conducted at Corning to determine the effectiveness of such glasses as heat screens.

Reactive Power

L. A. Doggett (State College, Penna.) in his discussion of this subject in regard to the typical modern system recommended agreement on the assumption that there is but one type of reactive power, that associated with the storage and discharge of magnetic energy. Thus defined a synchronous motor may either receive or supply reactive power and a static condenser would always supply reactive power. As to the sign he recommended consistency with the convention of counterclockwise rotation of vectors and with conventions of polar coordinates which call for the negative sign in front of jQ, when jQ represents reactive power of the magnetic type. Experience has led the discusser to believe that reactive power follows a law similar to the law for the conservation of energy.

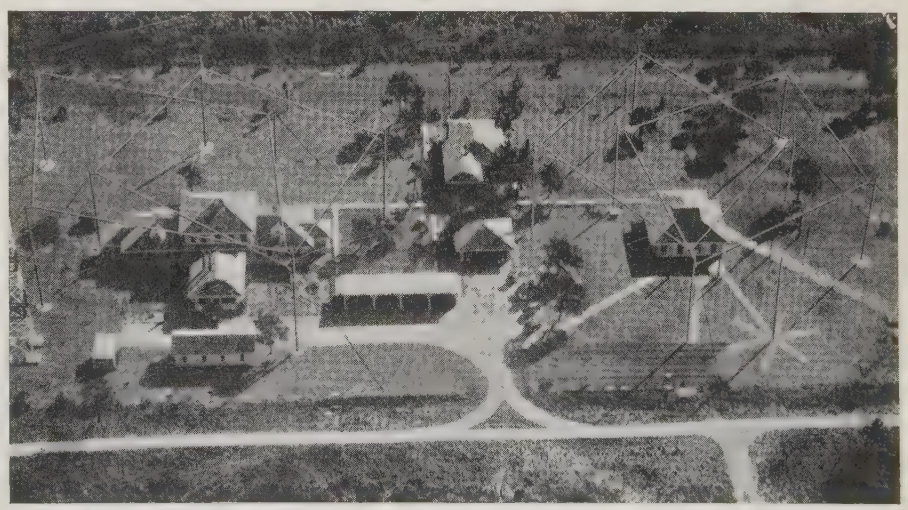
F. W. Godsey, Jr. (New Haven, Conn.) in his discussion cited good reasons which led him to make the following suggestions. The term reactive power in single-phase circuits should refer only to the fundamental frequency component of the reactive power, and that when both current and voltage waves have harmonics that the total reactive power component be called the total reactive power. In regard to polyphase systems it was found that for the balanced system with sine wave voltages and currents, the same conditions apply as in the single-phase case. He suggested that reactive power refers only to the fundamental frequency component of the out-of-phase power; this is the value usually measured by reactive kilovoltampere meters since voltage waves seldom have large harmonics. Let the entire out-of-phase component be known as the total reactive power. If a further description of a particular case is necessary, oscillograms must furnish it in almost every instance.

Another discusser, V. Karapetoff (Ithaca, N. Y.), was of the opinion that any definition of power factor which cannot be realized with fairly simple practical measuring instruments will remain a dead letter; on the other hand, a definition which may not be quite rigorous theoretically may prove to be of great practical usefulness if the corresponding measurements are simple and can be readily understood by the average operating engineer. The discusser proposed, for the purposes of defining and computing the value of the power factor on an unbalanced polyphase circuit, even with non-sinusoidal currents and voltages, that the reactive power or energy be defined as the reading of a polyphase wattmeter or watt-hour meter with its potential windings quadratured.

R. D. Evans (East Pittsburgh, Pa.) described and illustrated recent developments of power diagrams which have been extended until they now correlate all of the energy flow relations in circuits having both resistance and reactance. Two new vectors are added, R and X, whose projections on the x-axis represent, respectively, the instantaneous dissipative power Ri^2 and the instantaneous flow of energy in reactive circuit elements. He also discussed the plotting of inductive reactive voltamperes and gave good reasons for the selection of the method with counterclockwise rotation of vectors. In regard to the sign the discusser favored plotting inductive reactive power positive, that is as $P + jQ$, as it seemed more readily to provide correlation with energy flow and energy storage in simple equivalent circuits than the opposite convention. He also thought it desirable to consider the flow of reactive power as positive in the direction from the overexcited generator to the normal or inductive resistance load.

Another discusser, J. J. Smith (Schenectady, N. Y.), considered the definitions for

Telephone Links to Colombia and Venezuela



THE horizontal rhombic antennas of the Miama, Fla., receiving station of the American Telephone and Telegraph Company, are shown above. They are the receiving antennas for radio-telephone circuits to the Bahamas and South and Central American points. The Bell System was linked with Venezuela on December 18, 1932, and with Colombia 4 days later by short-wave radio stations near Miami and in the South American countries. North America now has direct telephone connections with 7 South American countries; other links are giving service to Argentina, Brazil, Chile, Peru, and Uruguay.

apparent power given in the papers by W. V. Lyon and V. G. Smith. In the case of unbalanced polyphase circuits it was his belief that the definition suffered from a number of disadvantages. Complicated equations might become involved in finding out what the maximum power is; also the solution might require physically impossible circuits and these drawbacks complicate the practical use of the definition. He suggested a definition of apparent power based upon equal effective currents in all the lines and a definite single value for the voltages since they are fairly well balanced in most cases.

Part of a discussion by C. C. Herskind (Schenectady, N. Y.) draws attention to the fact that in view of the increasing use of vacuum tube devices in power applications, it is important that the effects of harmonics on any definition of power factor be fully understood. In the past, unbalance power has been a source of trouble in the determination of power factor and therefore he believed it should also be covered by the new definition. To take these factors into account, the discusser suggested that the power factor in a polyphase circuit should be defined as P/P_{ap}.

C. H. Sanderson (New York, N. Y.) discussed the paper entitled "Operating Aspects of Reactive Power." He felt that this paper presented a clear and logical view of a subject which is far from being clear and logical to the majority of operators. The system of reasoning presented by the author which may commonly be applied to any portion of the power system under any condition of power flow and which permits a further simplification of instrument indications and log records, he believed would no doubt receive the hearty endorsement of all system operators.

C. A. Corney (Boston, Mass.) also discussed this subject from an operating point of view. It was his belief that the adoption of the conventions proposed by Mr. Johnson would simplify the discussion and handling of reactive power. He explained that in the past there had been considerable confusion due to the fact that individuals as well as groups of operating men had built up their own nomenclature and conceptions which were fundamentally sound but differed in the manner in which the terms were applied and to the point of reference. For example, it is essential to know whether "lag" or "lead" is with reference to the bus or to the incoming line. Thus a common nomenclature for handling reactive power is an important factor in successful interconnection.

M. G. Malti (Ithaca, N. Y.) in his discussion of this subject proved mathematically that the sum of the readings of p-1 wattmeters properly connected in a polyphase circuit give the power p supplied to that circuit irrespective of the wave form of voltage and current or of the balance or unbalance of the system. The definitions of reactive power and power factor which were derived by the discusser were useful physically and measurable practically.

B. E. Lenehan (Newark, N. J.) discussed the subject from the standpoint of representing in the customary cyclic variation of the instantaneous values of an alternating voltage or current by the projection of a line on the vertical axis rotating once a cycle. In his opinion until the use of either voltage or current is standardized as a reference vector in making vector diagrams, there is no choice between $P + jQ$ and $P - jQ$ for inductive loads. When the reference vector is chosen the sign of Q is or should automatically be determined. It is the same in direction as the vector not used as reference.

H. S. Baker (Niagara Falls, Ontario) inquired, since it appears impossible to define the exact meaning of "reactive volt amperes" or "power factor" as applied to complex circuits, and since there is no hope of such a definition being of practical use if agreed upon, should we not continue to do our metering and billing in the customary manner but use some other terms for these physical quantities now actually measured and used.

During the meeting an informal ballot was taken in regard to the preference of sign in designating inductive reactive kilovoltamperes in power triangles. Deductions have been made for the duplications of names and institutions previously appearing in a mail ballot. An analysis of the vote showed that the negative (downward) convention for inductive reactive power in triangular power diagrams is favored over the positive (upward) convention in about the ratio of 3 to 2. This is the case whether the individual or institutional index be taken.

A New Lumen Planimeter

Starting from the polar curve representing the light output of a lamp, it is possible by means of the construction of a Rousseau diagram to measure the total light output, provided the polar curve is the same in the different meridian planes, or the curve is at least a good mean. An ordinary planimeter then can be used to measure the total light output.

The new lumen planimeter, shown in Fig. 1, was constructed during the fall of 1932 in the electrotechnical laboratory of the Royal Technical College in Copenhagen, Denmark, and has been reported by J. G. C. Weber. This planimeter eliminates the construction of the Rousseau diagram and gives directly the luminous flux by measuring the polar curve. The accuracy obtainable with the equipment constructed was within one per cent, but could be increased if desired.

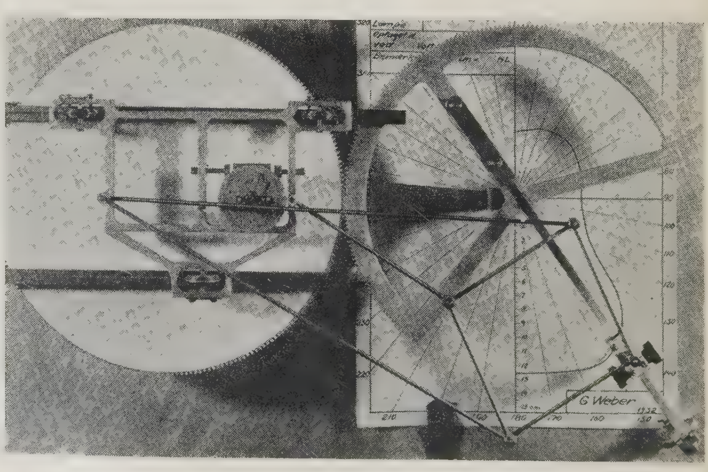


Fig. 1. Lumen planimeter for measuring light output directly from the polar curve

Frank B. Gilbreth's Books Requested.—The Newark (N. J.) College of Engineering desires to acquire copies of the following books by the late Frank B. Gilbreth: Field System; Concrete System; Bricklaying System; Motion Study Primer of Scientific Management; Time Study, the Science of Obtaining Methods of Least Waste. These books will be placed in the Gilbreth Memorial Room which has been dedicated to the memory of this pioneer. The room now contains some of his papers, pictures, and instruments, and a fairly complete library of works on scientific management and human relations. This request for the books is made by Soloman Fishman (A'28), assistant professor in industrial engineering at Newark College of Engineering; he states that, if necessary, a reasonable amount will be paid for the books.

Centenary of Gaston Planté to Be Celebrated.—The Société Française des Électriciens has taken the initiative for a celebration to be held in 1934 of the centenary of Gaston Planté, who contributed much to the early development of the storage battery. Volta's discovery of the galvanic battery in 1800 initiated research in this field of electrochemistry and further discoveries were made by Gautherot in 1802, and by Ritter in 1803. Other experimenters entered the field, but it remained for Planté to develop a valuable form of cell as a result of his study of the properties of metals for the accumulation of oxygen. Planté began his study of electrolytic polarization in 1859, and as a result of his experiments devised a battery for the storage of electrical energy, consisting of 2 sheets of lead separated by strips of rubber and rolled into the form of a spiral. It was not until 1881 that other experimenters made important discoveries in this field. Planté's name has been perpetuated in connection with the storage battery, by the so-called Planté plate; this type of plate, as distinguished from the others, consists of a sheet of lead on which the active material is formed electrochemically from the lead of the plate itself. To celebrate the centenary of Gaston Planté, an international committee is being formed and will comprise the highest authorities of the scientific and industrial world; this committee will elaborate a program of commemorative ceremonies worthy of this great scientist.

Lightning Protection of Distribution Systems

An experimental investigation has been carried on by the engineering experiment station of Purdue University, Lafayette, Ind., in cooperation with the Utilities Research Commission, Inc., Chicago, Ill., during the 4 years 1928–32, to determine the effect of potentials, simulating those of lightning, upon 2,300/4,000 to 115/230-volt electric light and power distribution system. These investigations are described and summarized in a bulletin entitled "Lightning Protection of Distribution Systems and Transformers" by C. S. Sprague (A'26) and C. F. Harding (A'06, F'14). The bulletin, research series No. 42, may be obtained from the engineering experiment station, Purdue University, Lafayette, Ind., free to residents of Indiana, and at a cost of 50 cents to non-residents.

In general, the work described in this bulletin was centered upon the secondary distribution system, the distribution transformer, and the consumer's wiring circuit, as lightning damage commonly manifests itself at these points. The major part of the investigation has been performed upon several spans of outdoor distribution line, built especially for the project, on the campus of Purdue University. This line was constructed in accordance with the specifications frequently used in practice for 4-wire grounded-Y 2,300/4,000-volt primaries on the upper arm and with 3-phase 230-volt power secondaries and single-phase 115/230-volt 3-wire lighting secondaries on the lower arm. The majority of the results obtained are not, however, necessarily restricted to this one type of construction. Accounts of a few surge tests upon transformers of other manufacturers than those of the original project are also included.

It is felt that the conclusions which have resulted from this investigation will be of considerable assistance to the utility operator in his efforts to minimize service outages and interruptions, since several of the changes found to be beneficial have already been made in large distribution systems.

The principal results and conclusions drawn from the investigation were presented at the A.I.E.E. winter convention, New York, N. Y., January 25–29, 1932. This material was published in Electrical Engineering for September 1932, p. 639–42, with revisions which brought it up to that date.

Heating and Ventilating Guide for 1933 Now Available.—The 11th annual edition of The American Society of Heating and Ventilating Engineers' Guide, 1933, has recently been made available. This eleventh edition of the standard reference volume on heating, ventilating, and air conditioning has been extensively enlarged and revised to include the latest results of research in modern engineering practice. Compiled by the foremost engineers in the profession, the Guide, 1933, embodies in its 45 chapters not only the data developed at the A.S.H.V.E. research laboratory and cooperating institutes, but also the most practical and useful ideas of outstanding engineers. The text section of the Guide, 1933, contains 608 pages, supplemented by 180 pages of manufacturers' catalog data with an index to modern equipment, also 64 pages of the A.S.H.V.E. roll of membership. Copies are obtainable from the American Society of Heating and Ventilating Engineers, 51 Madison Ave., New York, N. Y., at a cost of $5.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. Electrical Engineering will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or to reject them entirely.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

Loading Transformers by Temperature

To the Editor:

There are some errors in my paper on "Loading Transformers by Temperature" published in the A.I.E.E. Trans. for April 1930, p. 776–90. For example, in eq 3 on p. 779, the term $(N + 1)$ was left out of the denominator. Also, eqs 4 and 5 cannot be used in the present form.

Eq 3 for the total winding rise should read as follows:

$$T = C - A = T_0\left(\frac{LNR^2 + 1}{N + 1}\right)^{n_0} + T_c(LR^2)^{n_c} \qquad (3)$$

As this equation stands it is, of course, impossible to obtain an explicit solution for R. By assuming a constant copper temperature ($L = 1$) and making the approximation $n_0 = n_c = 1$, the following equations are obtained:

$$R = \sqrt{\frac{T(N+1) - T_0}{T_c(N+1) + T_0N}} \qquad (4)$$

$$R = \sqrt{\frac{(C-A)(N+1) - T_0}{T_c(N+1) + T_0N}} \qquad (5)$$

Eqs 4 and 5 are analogous to eqs 4 and 5 in the original paper, which are in error.

The approximation involved in eqs 4 and 5 is undesirable, since it is pessimistic; i. e., it does not allow as much overload as might be carried. A more accurate approximation is given by the assumption given in eqs 6 and 7:

$$\left(\frac{NR^2 + 1}{N + 1}\right)^{n_0} = 1 + n_0\left(\frac{NR^2 + 1}{N + 1} - 1\right) \qquad (6)$$

$$(R^2)^{n_c} = 1 + n_c(R^2 - 1) \qquad (7)$$

Again, assuming $L = 1$, and assuming $n_0 = n_c = \frac{1}{m}$ gives the following more accurate alternatives to eqs 4 and 5:

$$R = \sqrt{\frac{mT(1+N) + (1-m)(1+N)(T_0 + T_c) - T_0}{T_0N + T_c(1+N)}} \qquad (4a)$$

$$R = \sqrt{\frac{m(C-A)(1+N) + (1-m)(1+N)(T_0+T_c) - T_0}{T_0N + T_c(1+N)}} \qquad (5a)$$

In general, the author considers it preferable to work directly from eq 3 even though no explicit solution is available, as the problem can easily be handled by plotting R as a function of T_0 and T_c for constant values of T, L, n_0 and n_c. The data in Tables II and III and the curves in Figs. 3 and 4 of the original paper were calculated from eq 3 corrected as shown above.

The following numerical example is given. Assume

$L = 1.0$ $\quad T_c = 15$ deg C
$n_0 = n_c = 0.8$ $\quad N = 2$
$m = 1.25$ $\quad T = 95$ deg C
$T_0 = 40$ deg C $\quad$ (0 deg C ambient)
Eq 3 gives $R = 1.52$
Eq 4 gives $R = 1.40$
Eq 4a gives $R = 1.48$

Very truly yours,
V. M. Montsinger
(Power Transformer Dept.,
General Electric Co.,
Pittsfield, Mass.)

Decibel and Decineper Charts

To the Editor:

Many calculations can be performed more easily and with a great deal less effort by the use of charts or slide rules. Charts or mechanical slide rules are particularly useful when the data to be obtained does not require extreme accuracy. The decibel and neper charts which the author has designed recently for the purpose of simplifying calculations of power gain and power loss in transmission lines or radio amplifiers, can be classified under this category. The decibel and decineper charts are similar, in a way, to the exponential slide rule, which was designed by the author and was announced in Electrical Engineering, June 1932, p. 400–1.

One of these charts is a current-voltage ratio decibel chart. It is calculated from the formulas $db = 20 \log_{10} \frac{E_2}{E_1}$ and $db = 20 \log_{10} \frac{I_2}{I_1}$. With this chart, decibel gain or decibel loss can be obtained, with fair accuracy, from zero to 200 decibels. The second chart is similar to the first except that it is calculated from the formula $db =$

$10 \log_{10} \frac{P_2}{P_1}$ and from it data for the power decibel can be obtained.

The third is the decineper chart. It is calculated from the formula, $dn = 5 \log_{\epsilon} \frac{P_2}{P_1}$. The decineper is used very little in the United States; the author therefore did not go to the trouble of extending the decineper scale above 11.51. If any one desires to get higher decibel values than 11.51 they can easily be obtained by adding 11.51 for every line above the first line used in the decineper loss or gain lines. For instance if the power loss of a circuit is, let us say, 3×10^{-4}, the chart will indicate 6 decinepers, but since 3×10^{-4} is 3 lines above the first, we therefore have to add $3 \times 11.51 = 34.53$. The answer is 40.5 decinepers. Similarly if the circuit had a gain of 3×10^4, then 3×10^4 is 4 lines above the first line, and the multiplying factor of 11.51 is 4. Multiplying 11.51 by 4 and adding the result to 6 gives 51.5 decinepers.

The transmission and radio engineer will find these charts a useful and practical instrument to save labor and time in solving problems involving decibels and decinepers.

Very truly yours,

Louis B. Sklar (A'30)
(816 North Sixth St.,
Philadelphia, Pa.)

Reactive Voltampere Conventions

To the Editor:

In connection with the group of articles on reactive power in the April 1933 issue of Electrical Engineering, p. 259–70, an invitation is given Institute members to submit comments regarding the assigning of a particular geometrical direction to reactive power of the inductive and capacitive forms when represented with power and voltamperes in power triangles.

I wish to vote emphatically for the principle of regarding lagging reactive power as negative, that is, drawing it downward from the right-hand end of the kilowatt base.

Very truly yours,

G. V. Mueller (A'28)
(Asst. Prof. of Elec. Engg.,
Purdue University, Lafayette, Ind.)

A New Use for X Rays Suggested

To the Editor:

I wish to offer some suggestions concerning the treatment of disease by the use of X rays, in the hope that qualified persons may use them in developing more effective treatments than the present ones in use.

We are well aware that ultra-violet rays have great germ killing power but lack penetrating power. The new soft X ray tubes, with thin windows and low anode to cathode electromotive force, show the same characteristics. While excellent for surface treatments these do not have the necessary penetration for deep seated infections, cancer, etc.

The hard X rays penetrate well but do not seem to have the germ killing ability of the soft ones. I suggest that we try to combine the 2 in the following manner:

The hard rays, or short wave-length ones, have very high frequency which may be lowered slightly by lowering the anode to cathode voltage of the tube; therefore it is possible, by the use of 2 tubes, with different applied voltages, to get 2 sources of X rays of slightly different wave-length, but both still short enough to penetrate well.

By passing both of these cones of X rays through the body of the patient, say from opposite sides or at any angle found best, the 2 cones will meet within the body. It is quite possible that the resultant effect will be the production of a fair amount of soft radiation within the body where it is so urgently needed to destroy the internal infections or abnormal growths.

This is of course an interference phenomenon; or, as the radio engineer would say, it is a sort of super-super-heterodyne effect. We get a beat frequency, corresponding to a soft X ray or to an ultra-violet ray, generated by the combination of the 2 hard rays of slightly different frequency and wave-length. The amount of the soft rays produced may be much greater than can be obtained by the usual secondary radiation of standard treatments, and it will probably be produced all through the body and not just at the bones or other hard tissue.

The softness of the resultant rays can be roughly adjusted by adjustment of the difference in the tube voltages. This does not necessarily require a different high voltage source, for the difference required can be easily obtained from a small power pack made very much like the standard radio power pack, and using standard radio rectifiers, in tandem, if necessary.

This is, of course, but a general suggestion, but I hope some one more familiar with the laws of optics than I am will find it worth while and will carry it through if it be possible.

Very truly yours,

T. G. Seidell (A'05)
(Professor of Electrical Engineering,
Georgia School of Technology,
Atlanta, Georgia)

The Unbalance Factor and Theory of Unbalance in 3-Phase Triangles

To the Editor:

In the dealing with unbalanced 3-phase triangles, it has been suggested that a "factor of unbalance" was a measure of the departure from a balanced condition. The writer intends to show that this factor is an indication of unbalance rather than a measure, and that, on the other hand, a "factor of balance," given below, has a wide bearing on theory and is a true measure of the degree of balance.

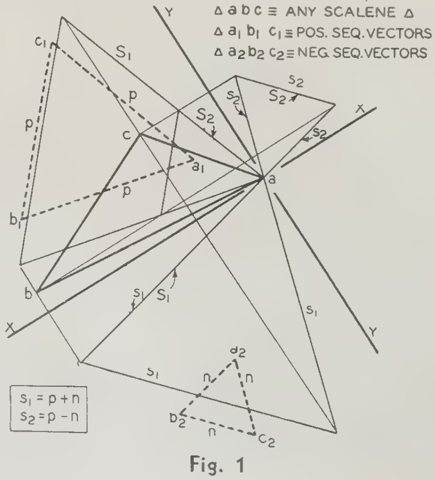


Fig. 1

The unbalance factor of a scalene triangle has been defined as the ratio of the lengths of the negative and positive sequence components, n/p. Hence, in an equilateral triangle, n is zero, and the unbalance factor is zero; in a triangle of maximum unbalance the factor is unity. But the

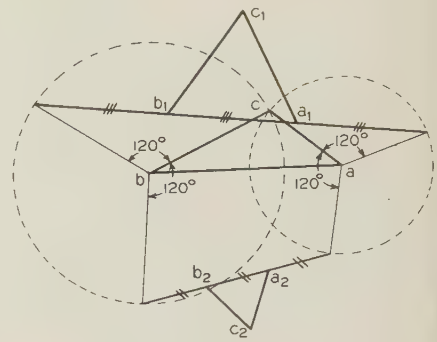


Fig. 2

geometry that lies beneath the symmetrical components shows that this ratio is not a *measure of the degree of unbalance*, and that the simple ratio $(p-n)/(p+n)$ is a *measure of the degree of balance* and may properly be called a "factor of balance."

In the following development of the theory of unbalance, the analytic proofs of certain statements are necessarily omitted for lack of space. These, however, may be verified by simple geometrical constructions.

(*a*). It is shown in Fig. 1 that a scalene triangle *abc* may be resolved into 2 equi-

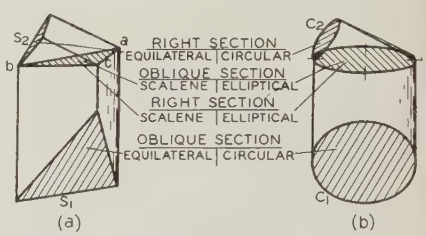


Fig. 3

lateral triangles (marked S_1 and S_2) by projecting the sides of triangle *abc* orthogonally *with respect to* a pair of rectangular axes (*XX* and *YY*), *onto* lines that are drawn parallel to either the positive phase sequence components a_1b_1 and a_1c_1, or to the negative sequence components a_2b_2 and a_2c_2. The positive and negative sequence vector triangles, $a_1b_1c_1$ and $a_2b_2c_2$, are obtained by a well-known construction. The axes *XX* and *YY* are parallel to the bisectors of any corresponding pair of sequence vectors, say, a_1b_1 and a_2b_2. The position of the origin is arbitrary and is chosen for convenience at vertex *a*. (Fig. 2, published in the A.I.E.E. Trans., v. 47, 1928, p. 341, is resubmitted here to clarify Fig. 1.)

The equilateral triangles S_1 and S_2 are the major and minor auxiliary triangles of triangle *abc*. They are *exactly* analogous to the major and minor auxiliary circles of an ellipse. The lines *XX* and *YY* are the major and minor axes of the particular triangle.

The space interpretation of this is given in Fig. 3(*a*). A scalene prism, the right section of which is the triangle *abc*, is cut by an oblique section that is the equilateral triangle S_1; also an equilateral prism, whose right section is traingle S_2, is cut by an oblique section that is congruent with triangle *abc*. The similarity of Figs. 3(*a*) and 3(*b*) is

apparent. It may be proved analytically that these figures are determined uniquely for any given scalene or elliptical right section of the vertical prism. Hence, in Fig. 1 the traingles S_1 and S_2 are unique for any triangle *abc*.

(*b*). In the December 1932, issue of Electrical Engineering, p. 886–7, it was shown in a letter from R. Laplante, entitled "Graphical Determination of the Symmetrical Components in a 3-Phase Unbalanced System," that the construction used on triangle *abc* in Fig. 4(*a*) gives the triangle *PPP*, equal in size and 180° out of phase with the positive sequence vector triangle of triangle *abc*. A similar construction (by erecting 30° − 30° − 120° isosceles triangles *inwardly* on the sides of triangle *abc*, and joining the vertices), gives triangle *NNN*, which is equal in size and 180° out of phase with the negative sequence vector triangle of triangle *abc*. These *inverted*, sequence triangles are both

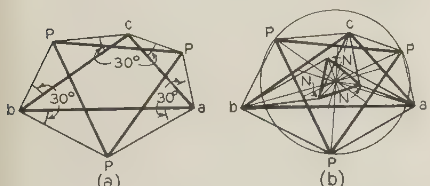


Fig. 4

shown in Fig. 4(*b*); they will be referred to below as triangle *P* and triangle *N*. All 3 triangles have a common median center, and the difference of the areas of the triangles *P* and *N* is the area of triangle *abc*.

(*c*). In Fig. 5 the median ellipse, or largest inscribed ellipse, trisects the medians and touches at the mid-points of the sides of triangle *abc*. Its center coincides with the median center of the triangle. It can

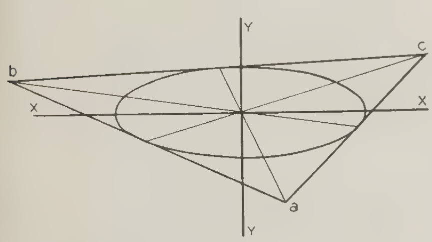


Fig. 5

be proved that the major and minor axes of this ellipse are the same (direction) as the major and minor axes of the triangle, and that they bisect the included angles between each of the corresponding pairs of positive and negative sequence vectors. It will be seen that the unbalance of this ellipse is the same as the unbalance of the triangle.

The ellipse in Fig. 6 is the largest *escribed* ellipse of the triangle *abc*. It is twice the size of the ellipse in Fig. 5, and is similar in phase and shape. For this reason it has the same axes as the triangle *abc*. The major auxiliary circle (C_1) of the escribed ellipse is now seen to be the escribing circle of the major auxiliary triangle S_1; the minor circle C_2 is the escribing circle of the minor triangle S_2. The major circle is then considered to be rotated from the plane of the paper, about axis *XX*, and projected into the ellipse. If the major triangle be rotated in the same plane as circle C_1, it is clear that its projection is triangle *abc*. Also, as the ellipse is projected into the minor circle C_2, about the axis *YY*, the triangle *abc* becomes the minor triangle S_2.

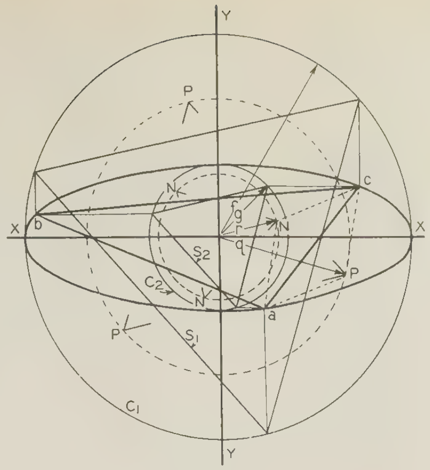


Fig. 6

The angle *d*, through which the circle C_1 and the triangle S_1 are projected about the major axis, *equals* the angle through which the ellipse and the triangle *abc* are projected about the minor axis. Therefore the dihedral angle between the plane of triangle S_1 and the plane of triangle *abc*, in Fig. 3(*a*), equals the dihedral angle between triangle *abc* and triangle S_2.

(*d*). It is found by analysis that $p = {}^1/_2(s_1 + s_2)$, and $n = {}^1/_2(s_1 - s_2)$, where s_1 and s_2 are the lengths of the sides of the triangles S_1 and S_2. This may be verified empirically by the construction of Fig. 1. In Fig. 6 it is seen that:

$f = s_1/\sqrt{3}$, circumscribes triangle S_1
$g = s_2/\sqrt{3}$, circumscribes triangle S_2
$q = p/\sqrt{3}$, circumscribes triangle P
$r = n/\sqrt{3}$, circumscribes triangle N

Whence:

$q = {}^1/_2(f + g) \quad r = {}^1/_2(f - g)$
$p = {}^1/_2$(sum of the semi-axes of the ellipse)
$n = {}^1/_2$(difference of semi-axes of the ellipse)

The ratio $(p - n)/(p + n) = s_2/s_1 = g/f = \cos d$.

It is now obvious that the degree of unbalance of a triangle depends directly upon the angle *d through which it is the projection of* an equilateral (major) triangle about a major axis, or upon the (same) angle *through which it may be projected into* an equilateral (minor) triangle about a minor axis. The cosine of this angle is given above, and is a direct measure of the degree of balance. If the factor of balance is then defined as $\cos d$; the factor of an equilateral triangle is unity; in the case of maximum unbalance, it is zero.

The "factor of unbalance" previously considered, equals n/p. From Fig. 6 this

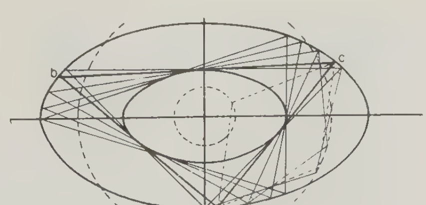


Fig. 7

ratio equals $r/q = (1 - \cos d)/(1 + \cos d)$, which lacks interpretation in the above theory except as an *indication* of unbalance.

(*e*). The nature of the family of triangles, possessing the same scalar values of sequence components, is interesting at this point. The triangles shown in Fig. 7 have the same factor of balance, and are all projected through the same angle *d* from the same major equilateral triangle S_1. Each triangle has the same area. For each different triangle in the family, the major triangle has a different inclination with the major axis (or the triangle S_2 in Fig. 6 may be considered to be rotated to a new position in circle C_1), before being projected. The dotted circles are the loci of the vertices of triangles *P* and *N* for all the scalene triangles of the family.

The writer is gratefully indebted to H. S. Baker of Niagara Falls, Ontario, for Fig. 1, and to C. F. Gummer of Queen's University for the suggestion and valuable proof of Fig. 5.

Yours very truly,
J. H. Baker (Enrolled Student '31)
(Queen's University,
Kingston, Ontario, Can.)

Engineering Foundation

Ten Year Study on Arch Dams Completed

An investigation centered on problems of constructing and designing arch dams, carried on by the Engineering Foundation for the past 10 years, recently has been completed. The results are stated to point the way to economies in construction and to extend scientific knowledge of dams, with which power development, irrigation, water supplies of cities, flood control, and security of life and property are concerned.

Four of the most important findings are that models of arch dams will react in a manner similar to the structure itself, making possible extensive savings; that some types of tension cracks will not affect the safety of the dam; that the chemically generated heat of the concrete plays an intrinsic part in the serviceability of the structure; and that concrete dams are not stationary but "flow" to a slight degree in response to water pressure. In other words, concrete is slightly plastic under high pressure.

Elaborate experiments were made on an arch dam 60 ft high built on Stevenson Creek in the Sierras, about 60 miles from Fresno, Calif. Supplementing these experiments, 3 small models of the Stevenson Creek Dam were constructed at Princeton University, and models of this and other dams were built by the United States Bureau of Reclamation at the University of Colorado. Many large dams previously constructed also were studied.

The committee on arch dam investigation was appointed in 1922 with Prof. C. Derleth, Jr., of the University of California, as chairman. He was succeeded in 1926 by Prof. C. D. Marx of Stanford University, former chairman of the engineers' advisory board of the Reconstruction Finance Corporation. Seventy-five organizations con-

tributed more than $125,000 in cash to further the inquiry, and contributions of services and materials brought the total value above $200,000.

Flag of 11th Engineers Presented to Engineering Societies

One of the 2 national flags of the 11th Engineers, U.S. Army, a New York regiment that became famous for the part it played in the battle of Cambrai in November 1917 while building railroads on the British front in France, was presented to the United Engineering Trustees, Inc., on June 15, 1933, by Mrs. William Barclay Parsons, widow of Gen. William Barclay Parsons, who commanded the regiment during a large part of its 2 years of service in France. The United Engineering Trustees plan to display the flag with the flags of other engineer regiments now in their possession in the entrance hall of the Engineering Societies Building, New York. The flag is the national colors, made of bunting, and was used by the regiment for general service during its entire period of war service in France.

A group of approximately 40 representatives of the 11th Engineers Regiment, the engineering societies, and of the family of General Parsons gathered for the presentation. G. L. Knight (A'11, F'17), a trustee of United Engineering Trustees, presided. Colonel A. S. Dwight, connected with the regiment from its organization and now its senior officer, gave a brief history following the presentation by Mrs. Parsons. Mr. Knight accepted the flag on behalf of the United Engineering Trustees, representing the national engineering societies.

G. L. Knight Appointed Trustee of U.E.T., Inc.

By action of the board of United Engineering Trustees, Inc., May 22, 1933, G. L. Knight (A'11, F'17) was appointed a trustee of that organization to fill the vacancy caused by the resignation of A. W. Berresford (A'94, F'14, past-president).

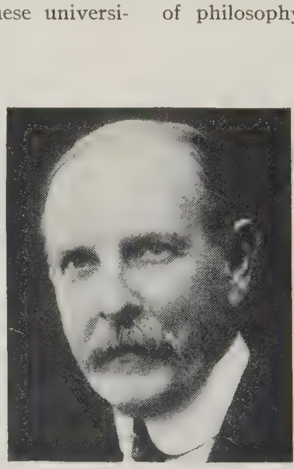
Mr. Knight will serve for the complete term, which expires January 1935. He is vice-president in charge of mechanical operations, Brooklyn Edison Company, Brooklyn, N. Y.

Personal Items

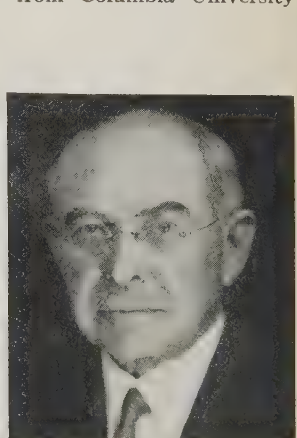
A. E. Kennelly (A'88, M'99, F'13, Life Member and past-president) has been elected an Honorary Member of the Institute, the highest grade of membership available. Announcement of this election was made during the summer convention, Chicago, Ill., June 26–30, 1933. He was born at Colaba, near Bombay, East India, in 1861, and was educated at private schools in Great Britain, France, and Belgium, including the University College School in London. He has received the honorary degrees of master of arts from Harvard University, 1906; and doctor of science from the University of Pittsburgh, 1895, and from the University of Toulouse, France, 1922. In 1875 Doctor Kennelly became assistant secretary of the Society of Telegraph Engineers (now Institution of Electrical Engineers) London, and in the following year entered the Eastern Telegraph Company as an operator. He was appointed assistant electrician in Malta in 1878, chief electrician of a cable repairing steamer in 1881, and senior ship electrician on submarine cables in 1886. Coming to the United States in 1887, Doctor Kennelly was engaged as principal electrical assistant to Thomas A. Edison until 1894. During 1893 he also was consulting electrician to the Edison General Electric Company, and to the General Electric Company of New York. From 1894 to 1901 he was a member of the firm of Houston and Kennelly, consulting electrical engineers of Philadelphia, Pa. In 1902 he had charge of the laying of the Vera Cruz-Frontera-Compeche cables for the Mexican government. Between 1902 and 1930 Doctor Kennelly was professor of electrical engineering at Harvard University, and held the same position at Massachusetts Institute of Technology between 1913 and 1924. For the latter organization he also was director of electrical engineering research and chairman of the faculty between 1917 and 1919. In 1930, he became professor emeritus of electrical engineering for both Harvard University and Massachusetts Institute of Technology. During 1918 he was civilian liaison officer for the Signal Corps of the United States Army in France. During the year 1921–22 he represented 7 cooperating American universities as first exchange professor in engineering and applied science at several French universities, and in 1931 was visiting electrical engineering lecturer to Japanese universities. Between 1924 and 1927 he was research associate to the Carnegie Institution. Doctor Kennelly has published about 28 books, of which he is the sole author of 10, included in which are "Theoretical Elements of Electro-Dynamic Machinery," "Electric Lines and Nets," "Wireless Telegraphy," "Electrical Vibration Instruments," and several on hyperbolic and other complex functions. Perhaps Doctor Kennelly's most important works are contained in his papers, numbering over 300, many of which have been presented before leading scientific and technical organizations in the United States and abroad, and have been widely distributed in technical publications. One of his chief contributions to applied science is a paper on "Impedance" presented in 1893 before the A.I.E.E. and containing the first use of complex numbers as applied to Ohm's law in a-c engineering. Doctor Kennelly in 1902 expounded a theory on the influence of solar ionization in the atmosphere on long distance radio transmission, which has since been verified experimentally and has resulted in the naming of the so-called ionized layer of reflection, the Kennelly-Heaviside layer. Doctor Kennelly is a member of a large number of organizations, most of them technical, in the United States and other countries; in many of these he is an honorary member, president, or past-president. Doctor Kennelly also has served as a delegate to several international electrical conferences over a period of many years. He has been active in the Institute since he joined in 1888, and at present is a member of several committees. He has received the following medals and awards: Institution Premium, 1887, and the Fahie Premium, 1889, from the Institution of Electrical Engineers, Great Britain; Longstreth Silver Medal, 1916, and Howard Potts Gold Medal, 1917, from the Franklin Institute; Third Order Mejitieh, Egypt, 1885; Chevalier Legion d'Honneur, France, 1922, Medal of Honor of the Institution of Radio Engineers, 1932.

R. A. Millikan (M'22), as formally announced at the summer convention, Chicago, Ill., June 26–30, 1933, has been elected Honorary Member, the highest grade of membership in the Institute. He was born at Morrison, Ill., in 1868, and received the degree of bachelor of arts from Oberlin College in 1891 and that of doctor of philosophy from Columbia University

R. A. MILLIKAN



A. E. KENNELLY



E. W. RICE, JR.

EDWARD WESTON

G. A. HAMILTON

W. L. R. EMMET

in 1895. In the years 1895–96, he attended the universities of Berlin and Göttingen. He has received the degrees of doctor of science, doctor of laws, and doctor of philosophy from several universities in the United States and other countries. From 1891 to 1893 he tutored in physics at Oberlin College, and in 1896 became assistant in physics at the University of Chicago, becoming assistant professor in 1902; from 1906 to 1910 he was associate professor, becoming professor in the latter year, and remaining at the University of Chicago until 1921. Since 1921 he has been director of the Norman Bridge Laboratory of Physics and chairman of the executive council of the California Institute of Technology, Pasadena. Probably the best known of Doctor Millikan's earlier works are his oil drop experiments, whereby the absolute value of the charge on the electron was determined. His work on the accurate determination of the so-called h constant by experiments on the photoelectric effects also are of considerable importance in the structure of the atom. He later did considerable work toward the definite bridging of the gap between light and X ray phenomena, and more recently has become well known for his experiments on the so-called "cosmic" or Millikan ray. His contributions to experimental physics have been of special importance to electrical engineers. In his work of instruction, he has evidenced rare ability to impart his own extraordinary scientific knowledge to others. Doctor Millikan is the author of several books, most of them dealing with physics and education, and has written many technical papers on physical topics. He is a member of many societies in the United States and other countries, and has served as president of the American Association for the Advancement of Science, 1929, and the American Physical Society, 1916–18. Since 1917, he has been vice-chairman of the National Research Council, of which he was one of the initiators. In 1922, he was an exchange professor to Belgium. He was commander, lieutenant-colonel, Signal Corps, U.S. Army, 1918, and chief of the science and research division of the Signal Corps. Among the medals and awards which he has received are: Comstock Prize of the National Academy of Sciences, 1913; Edison Medal of the A.I.E.E., 1922; Hughes Medal of the Royal Society of Great Britain, 1923; Nobel Prize in physics, 1923; Faraday Medal of the London Chemical Society, 1924; Mattencci Medal of the Societa Italiana della Scienze, 1925; gold medal of the American Society of Mechanical Engineers, 1926; Messel Medal of the Society of the Chemical Industry (British) 1928; gold medal of the Society of Arts and Sciences (for his theory of creation of cosmic rays) 1929; Chevalier de l'Ordre National de la Legion d'Honneur, 1931.

E. W. Rice, Jr. (A'87, M'88, F'13, Member for Life, and past-president) was born at LaCrosse, Wis., in 1862. While attending school in Philadelphia, Pa., in 1876, he came in contact with Prof. Elihu Thomson, then a teacher in the high school. In 1880 when Professor Thomson went into electrical manufacturing, young Rice became his assistant. After 3 years with Professor Thomson in New Britain, Conn., both went to Lynn, Mass., upon the organization of the Thomson-Houston Electric Company. Here he was plant superintendent from 1883 until 1888, when he became technical director. In 1892 upon the formation of the General Electric Company, Doctor Rice became vice-president; then president, 1913; and honorary chairman of the board, 1922; he now holds the latter position. He has received the honorary degrees of master of arts from Harvard University 1903, doctor of science from Union College 1906 and the University of Pennsylvania 1924, and doctor of engineering from Rensselaer Polytechnic Institute 1917. In connection with his receipt of the A.I.E.E. Edison Medal for 1931, a biographical sketch of Doctor Rice was given in Electrical Engineering for January 1932, p. 61, and a sketch of his career prepared by Dr. Elihu Thomson was given in the March 1932 issue, p. 195–6.

Edward Weston (A'84, M'84, Member for Life, and past president) was one of the distinguished group of individuals whose election as an Honorary Member of the Institute was announced during the summer convention at Chicago, Ill., June 26–30, 1933. Doctor Weston was born in Shropshire, England, in 1850, coming to New York City in 1870. Since then he has been active in the electrical industry in this country. In 1877 the Weston Company was incorporated to engage in the manufacture of dynamo electric machines; the need for practical instruments, however, caused him to establish the Weston Electrical Instrument Company in 1888. He was vice-president and general manager of this company from 1888 to 1905; president from 1905 to 1924; and since that time chairman of the board. A more complete biographical sketch of Doctor Weston's career, including his activities in the Institute and other technical organizations was presented in Electrical Engineering for April 1933, p. 282, in connection with the announcement of the award for the 1932 Lamme Medal of the A.I.E.E.

W. L. R. Emmet (A'93, M'94, Member for Life and past-vice-president) has been elected an Honorary Member of the Institue, as announced at the summer convention held in Chicago, Ill., June 26–30, 1933. This is the highest grade of membership in the Institute, and Doctor Emmet is well qualified for this rank. He was born at Pelham, N. Y., in 1859, graduating from the U.S. Naval Academy in 1881. In 1887 he joined the Sprague Electric Company, being active in electric railroad development, and for a short time after 1890 he was with the Westinghouse Electric and Manufacturing Company. He later joined the Edison General Electric Company, and in 1900 started his work in the development on the Curtis steam turbine, on which he made many important improvements. He was the first to point out the great importance of high vacuum in the operation of turbines, and also initiated the use of the turbine for ship propulsion (1907). More recently, he has been active in the development of turbines using mercury vapor instead of steam. A biographical sketch of Doctor Emmet was presented in Electrical Engineering for November 1932, p. 818, in connection with his having received the John Scott Medal award.

G. A. Hamilton (A'84, M'84, F'13, and Member for Life, and past vice-president) has been elected an Honorary Member of the Institute, as announced at the summer convention held in Chicago, Ill., June 26–30, 1933. Mr. Hamilton, a charter member of the Institute and its first vice-president, was born in Cleveland, Ohio, in 1843. He early showed great interest in electricity and while still a boy built a modest telegraph line himself. Between 1860 and 1873, he was in telegraph and railway signaling service, being a messenger at Salem, Ohio, in 1861, and later in the same year manager of the Atlantic and Great Western Railroad office at Ravenna, Ohio. After a brief illness in 1863, he went to Pittsburgh, Pa., as operator and manager of the Inland Company, and in 1865 he became manager of the United States Telegraph Company's office at Franklin, Pa. He returned to Pittsburgh in 1866 as chief operator and circuit manager, remaining until 1873 when the Western Union Telegraph Company absorbed this company. Between 1873 and 1875 he was assistant to Prof. Moses G. Farmer of Boston, Mass., a pioneer electrical inventor engaged in the manufacture of general electrical apparatus and machinery. Here he received much valuable experience. In 1875 he became assistant electrician of

the Western Union Telegraph Company in New York, N. Y., participating in the establishment and maintenance of the first quadruplex telegraph circuit and carrying out experiments preliminary to establishing the Wheatstone high-speed automatic system in the United States. In 1876, Mr. Hamilton was appointed chief electrician of the repair expedition of the Key West-Havana cable. In 1889 he became engineer for the Western Electric Company, New York, N. Y., being given supervision and care of the department for the production of fine electrical instruments, and retained this position until his retirement in 1909. Mr. Hamilton served the Institute as its national treasurer continuously between 1895 and 1930, and was a member of the Edison Medal and executive committees for many years previous to 1930. He is a member of the Institution of Electrical Engineers (Great Britain), Société Française des Électriciens, Société Française de Physique, and Société Belge d'Astronomie.

C. F. Scott (A'92, M'93, F'25, HM'29, Member for Life and past-president) professor of electrical engineering and for the past 22 years head of that department at Yale University, New Haven, Conn., retired from active service at the end of the college year just completed. He was born in Athens County, Ohio, in 1864, and after attending Ohio University at Athens for a while, he entered Ohio State University at Columbus, from which latter institution he graduated in 1885 with the degree of bachelor of arts. He then spent $1^1/_2$ years at The Johns Hopkins University, Baltimore, Md., in post graduate work. He has received the honorary degrees of master of arts from Yale University, doctor of science from the University of Pittsburgh, and doctor of engineering from Stevens Institute of Technology. While at Johns Hopkins University, he taught in the Baltimore and Ohio Railroad apprentice course. He then went into construction work with a company that was installing an a-c lighting plant in the Baltimore locomotive works. Doctor Scott entered the testing department of the Westinghouse Electric and Manufacturing Company at Pittsburgh in 1888, commencing on night duty in the dynamo room, from which he graduated to the laboratory where he assisted Nikola Tesla in his work on a-c motors. Later on he was given charge of the experimental work on the tests for motors. In 1891 he was appointed assistant electrician for the company, and in 1897 was made chief electrician, continuing in that capacity until 1904, when he became a consulting engineer of the company, having held this position ever since. Among the many important contributions to the electrical art which Doctor Scott has made, is the well-known Scott connection which he devised in 1892 for the interconnection of 2-phase and 3-phase power systems. He is stated to be the first man to measure corona losses on transmission lines, and the first to suggest the use of water to cool oil insulated transformers. In 1911 he severed his active connection with the Westinghouse company to become professor of electrical engineering at Sheffield Scientific School of Yale University, and was head of the department of electrical engineering from that time until his retirement which has just taken place. Doctor Scott has been a prolific contributor to the technical press and to the discussions of electrical development before the Institute and other engineering societies. He also has contributed much to the development of present methods of engineering education. His interest in technical education led to the establishment of the Westinghouse Club which has aided thousands of student engineers, and to the formation of the *Electric Journal* in 1904, to which he has been a frequent contributor. For many years he has actively served the Institute in various capacities, having been a representative of the Institute on several bodies, and a member of many of the Institute's committees. At present he is a member of 8 of the Institute's committees or joint bodies. He has

C. F. SCOTT

long been an ardent advocate of the system of Sections and Branches of the Institute. His advocacy of the erection of a building for headquarters of the national engineering societies led to the receipt of a gift from Andrew Carnegie which made possible the Engineering Societies Building. He was chairman of the building committee. He also was active in the formulation of the Federated American Engineering Societies, now American Engineering Council. He is a member of the Engineers' Society of Western Pennsylvania, president 1902; the Society for the Promotion of Engineering Education, president 1921–23; The American Society of Mechanical Engineers; the Illuminating Engineering Society; and other technical organizations. The A.I.E.E. awarded to him its 1929 Edison Medal for his contributions to the science and art of polyphase transmission of electrical energy, and he has been awarded the Lamme Medal by the Society for the Promotion of Engineering Education.

R. A. Hentz (A'14, M'26, F'29) electrical engineer for the Philadelphia Electric Company, Philadelphia, Pa., has received honorable mention in connection with the 1932 A.I.E.E. national prize for best paper. His paper, written in collaboration with J. W. Jones (A'22) was "Stability of Conowingo Hydroelectric Station, Philadelphia Electric Company System." Mr. Hentz was born in New York, N. Y., in 1889, and graduated from Cornell University, Ithaca, N. Y., in 1911. He then joined the organization of the Philadelphia Electric Company being an assistant in electrical distribution until 1913, assistant in electrical design of stations until 1916, chief electrical designer on station electrical design until 1920, assistant engineer of station electrical design and construction until 1925, becoming engineer in charge of the station electrical division, handling both design and construction, in 1925. Upon reorganization of the company in 1929, he was appointed electrical engineer, the position which he now holds. He has been associated with the electrical apparatus committee of the National Electric Light Association since 1923, having been chairman for the year 1929–30; he also has been a member of the power systems engineering committee of that organization since 1930. For the Institute, he was a member of the committee on protective devices 1924–26, and the committee on electrical machinery 1926–27.

H. A. Frederick (A'12, M'24, F'28) transmission instruments director, Bell Telephone Laboratories, Inc., New York, N. Y., has, with his co-author, H. C. Harrison (A'19), received honorable mention in connection with the 1932 A.I.E.E. national prize for best paper in theory and research, for the paper entitled "Vertically Cut Sound Records." Mr. Frederick was born in Essex, N. Y., in 1887. He received the degree of bachelor of science in mathematics and physics from Princeton University in 1910, and degree of electrical engineer from the same institution in 1912. Between 1912 and 1925 he was with the Western Electric Company, Inc., New York, N. Y., being first engaged on research studies on telephone receivers and amplifiers until 1914, on development studies of telephone receivers and transmitters until 1916, on development studies of telephone apparatus chiefly for special uses by the government in the war until 1918, and from then until 1925 he was in charge of development studies on telephone instruments. Since 1925 he has been with the Bell Telephone Laboratories, Inc., in charge of development studies of transmission instruments including recording and reproduction of sound.

Irwin Olcott (Enrolled Student) has, with his co-author, E. R. Gaerttner (Enrolled Student), received the 1932 A.I.E.E. North Central District prize for Branch paper for the paper entitled "Magnetism and Diamagnetism." Mr. Olcott was born in Denver, Colo., in 1911, and received the degree of B.S. in E.E. from the University of Denver in 1932. He is now studying at the State University of Iowa, Iowa City. His master of science thesis is on the design of an X ray tube to be used in the determination of the crystal structure of spectroscopically pure bismuth. He was student assistant in the physics laboratory at East High School, Denver, Colo., during 1928–29, and was assistant chemist, Longmont Farmers Milling and Elevator Company, Denver, 1930–31, and laboratory instructor, department of electrical engineering, University of Denver, summer 1931. Mr. Olcott received a tuition scholarship to the University of Denver, and has received the following honors: Mu Sigma Tau (electrical engineering), Pi Delta Theta (mathematics), Delta Chi

(chemistry), Alpha Nu (astronomy), and Delta Epsilon (science). He also has been secretary of the University of Denver Branch of the Institute.

H. C. Harrison (A'19) special transmission instruments research engineer, Bell Telephone Laboratories, Inc., New York, N. Y., has, with his co-author, H. A. Frederick (F'28), received honorable mention in connection with the 1932 A.I.E.E. national prize for best paper in theory and research for the paper entitled "Vertically Cut Sound Records." Mr. Harrison was born in Scribner, Neb., in 1887, and received the degree of bachelor of arts from Colorado College in 1910, and the degree of bachelor of science from Massachusetts Institute of Technology in 1913. After remaining at M.I.T. for a year as instructor, he joined the engineering department of the Western Electric Company that is now incorporated as the Bell Telephone Laboratories, in 1914. Here he first engaged in fundamental studies of receivers and carbon button microphones. This was followed by work on improved instruments and processes for recording and reproducing sound. Some 51 United States patents have been issued in his name covering such matters as microphones, recorders, reproducers, loud speakers, the orthophonic phonograph and sound measuring instruments.

J. W. Jones (A'22) senior engineer, system planning section, Philadelphia Electric Company, Philadelphia, Pa., has received honorable mention in connection with the 1932 A.I.E.E. national prize for best paper, for the paper by him and R. A. Hentz (F'29) entitled "Stability of Conowingo Hydroelectric Station, Philadelphia Electric Company System." Mr. Jones was born in Camden, N. J., in 1894, and graduated from the University of Pennsylvania in 1920 with the degree of B.S. in E.E. Previous to graduation he was for 2 years between 1917 and 1919 in the radio service of the Signal Corps, U.S. Army. He has been with the Philadelphia Electric Company continuously since 1920, having been employed successively in station construction, inspection, design, system planning, and transmission and distribution. He has been closely associated with the development of the Conowingo hydroelectric project and the Pennsylvania-New Jersey 220-kv interconnection.

A. H. Lovell (A'12, M'13) assistant dean and professor of electrical engineering, University of Michigan, Ann Arbor, has received honorable mention in connection with the 1932 A.I.E.E. national prize for best paper in public relations and education, for his paper entitled "Engineering Subjects, Electrical and Cognate in the Four-Year College Program of Electrical Engineering." Professor Lovell was born in Hamilton, Ontario, Canada, in 1884, and received the degrees of B.S. in E.E. from the University of Michigan in 1909, and M.S. from the same institution in 1914. After a varied experience in design and construction of power generation projects, he became an instructor at the University of Michigan in 1911, and a professor in 1919. In 1929, he was appointed assistant dean. A personal item regarding Professor Lovell was given in Electrical Engineering for January 1932, p. 55, in connection with his nomination as a director of the Institute.

J. B. Whitehead (A'00, M'08, F'12, and Life Member) dean of the faculty of engineering at The Johns Hopkins University, Baltimore, Md., and president-elect of the Institute for the 1933–34 term, has received the 1932 A.I.E.E. national prize for best paper in theory and research for the paper "Predetermination of the A-C Characteristics of Dielectrics" which he prepared jointly with Alfredo Baños, Jr. (A'31). Doctor Whitehead is well known to the membership of the Institute. Biographical sketches of him have appeared in Electrical Engineering for January 1933, p. 60, in connection with his nomination for the Institute's presidency; in the June 1932 issue, p. 421–2, in connection with his election to membership in the National Academy of Sciences; and in the December 1931 issue, p. 978–9, in connection with his having been awarded the Elliott Cresson gold medal of the Franklin Institute.

R. E. Doherty (A'16, M'27) dean of the engineering college of Yale University, New Haven, Conn., has received the 1932 A.I.E.E. prize for the best paper in public relations and education for his paper "Educational Aspects of Engineering and Management." Dean Doherty was for many years consulting engineer of the General Electric Company, Schenectady, N. Y., becoming professor of electrical engineering at Yale University in 1931, as announced in Electrical Engineering for June 1931, p. 450. Another personal item briefly outlining his achievements was given in the September 1932 issue, p. 672. Announcement of his appointment as dean of the new engineering college, which takes over the engineering division of Sheffield Scientific School of Yale University, was given in Electrical Engineering for January 1933, p. 64.

C. P. Potter (A'19, M'21, F'29) electrical engineer for the Wagner Electric Corporation, St. Louis, Mo., has received the 1932 A.I.E.E. South West District prize for best paper for "Heating and Overload Protection of Polyphase Motors." Mr. Potter is a graduate of the University of Illinois and his entire professional experience has been with the Wagner Electric Corporation, having joined this organization in 1909. He has for a number of years been in charge of the transformer and large motor engineering department. He has been active in local A.I.E.E. affairs, and is a past chairman of the St. Louis Section. He is also a member of the general engineering committee of the motor and generator section of the National Electric Manufacturers Association, and a member of the induction motor subcommittee of the A.I.E.E. electrical machinery committee.

F. M. Starr (A'30) of the distribution systems section of the central station engineering department of the General Electric Company, Schenectady, N. Y., has received honorable mention in connection with the 1932 A.I.E.E. national prize for initial paper for his paper entitled "Equivalent Circuits—I." As announced in Electrical Engineering for November 1932, p. 808–9, and p. 818, Mr. Starr received the Alfred Nobel prize for 1932, for this same paper. Mr. Starr was born in Fowler, Colo., in 1905, and graduated from the University of Colorado in 1928, with the degree of B.S. in E.E. He immediately entered the testing department of the General Electric Company at Schenectady, and in 1929 entered the engineering general department. Since 1930 he has been in the distribution systems section of the central station engineering department.

L. W. Robert, Jr. (A'31) who has attained prominence throughout the South as president of Robert and Company, Inc., consulting engineers and architects of Atlanta, Ga., has been appointed assistant secretary of the Treasury in charge of public buildings. He was born in Monticello, Ga., in 1887, and received the degree of B.S. in C.E. from Georgia School of Technology in 1908; during the following year he took post-graduate work in electrical engineering at the same institution. Between 1909 and 1912, he was inspector, designer, and engineer with P. A. Dallas, consulting engineer in Atlanta, handling responsible work on industrial plant design, steam plants and hydroelectric plants. Between 1912 and 1917, he was a member of the firm Dallas-Robert Company of Atlanta, and in 1917 organized the firm of Robert and Company. This firm handled some quarter of a billion dollars of major engineering projects involving industrial and public utility plants and all classes of architectural work. He has been a consulting engineer of several railway companies, and a director of many industrial corporations. Mr. Robert is a member of the American Society of Civil Engineers, The American Society of Mechanical Engineers, and the Georgia State Board of Architects. In his present capacity of assistant secretary of the Treasury in charge of public buildings he will participate actively in the building plans of the government.

N. W. Storer (A'95, M'03, F'13, Member for Life, and past vice-president) consulting railway engineer, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., was recently awarded the 1933 Lamme Medal of Ohio State University. He was born at Orangeville, Ohio, in 1868, and graduated from Ohio State University, Columbus, in 1891, with the degree of mechanical engineer in electrical engineering. Since 1891 he has been continuously with the Westinghouse company. His early work consisted chiefly in designing d-c generators and motors. Between 1904 and 1912 he was in charge of the railway department, and between 1912 and 1925 was general engineer assigned to special railway problems. Since 1925 he

has been consulting railway engineer, and has had a large part in the design of equipment for the railway, tunnel, and subway electrification carried on by the company. A total of 79 patents has been granted him. He has served the Institute on many of its committees, being at present a member of the standards and transportation committees. He is a member of The American Society of Mechanical Engineers, and of the Engineers' Club of New York.

G. H. Clamer (M'20) president and general manager of the Ajax Metal Company, Philadelphia, Pa., and who for approximately 40 years has been associated with the advancement of metal casting, has been awarded the Joseph F. Seaman gold medal by the American Foundrymen's Association for outstanding achievements in that field. The honorary degree of doctor of science also was conferred upon him recently by Ursinus College, Collegeville, Pa., because of his position and achievements in the scientific fields. He is a past-president of the American Institute of Metals and the American Foundrymen's Association, a member of the board of managers of the Franklin Institute, charter member of the American Electrochemical Society, and a member of other technical organizations. In addition to his affiliation with the Ajax Metal Company, he is also president and general manager of the Ajax Electric Furnace Corporation, Ajax Electrothermic Corporation, and Ajax Electric Company, Inc.

D. W. Roper (A'93, F'14, and Member for Life) formerly superintendent of the street department of the Commonwealth Edison Company, Chicago, Ill., has been transferred to the engineering department of the company and appointed assistant electrical engineer. The personnel and activities of the technical division of the street department have been transferred to the engineering department and will be designated the research division. In his new capacity, Mr. Roper will continue to direct the cable research and related work formerly carried on by the technical division of the street department.

L. K. Comstock (A'93, F'12, and Member for Life) chairman of the board of directors, L. K. Comstock & Company, Inc., electrical contractors, New York, N. Y., was recently elected president of The Merchants Association of New York. Mr. Comstock has been vice-president of the association since 1928. He was at one time superintendent of construction for the Western Electric Company, and later associated with the George A. Fuller Company of New York, before establishing his own firm in 1904.

A. O. Austin (A'04, F'25) formerly general manager, chief engineer, and vice-president of the Ohio Insulator Company, division of the Ohio Brass Company, Mansfield, Ohio, is to establish a practice of consulting engineering with headquarters at Barberton, Ohio. He intends to specialize in engineering work in connection with transmission and distribution of electrical energy for power and radio purposes. Among the firms which he will serve as consulting engineer is the Ohio Brass Company.

H. A. Stanley (A'08, M'19) formerly vice-president and general manager of the Fall River (Mass.) Electric Light Company, and more recently connected with the electrical engineering department of the Narragansett Electric Company, Providence, R. I., and the New England Power Engineering and Service Corporation, Boston, Mass., has joined the organization of the Berkshire Fine Spinning Associates, with headquarters at Fall River. Mr. Stanley's title is plant engineer.

W. A. Naudain (A'23) formerly meter departments supervisor of the Montreal Engineering Company, Ltd., Montreal, Quebec, Canada, for companies controlled by the International Power Company, Inc., has recently organized a firm under the name of Naudain and Company, and established an office at New York, N. Y., where the company is acting as manufacturers' export agents for a number of American manufacturers of electrical instruments and other engineering equipment.

H. C. Curtis (A'26) formerly an electrical engineer in the research department of the Allen-Bradley Company, Milwaukee, Wis., has organized the Curtis Development Company, Milwaukee, the duties of which will be primarily to develop new ideas. The company is set up to take ideas in their fundamental forms and develop them into salable products economically. The scope of the business consists of consulting, designing, developing, and manufacturing.

William A. Smith (A'23) formerly assistant chief engineer of the Ohio Insulator Company, Barberton, Ohio, has been appointed chief engineer of the company, succeeding A. O. Austin (F'25). Mr. Smith has been active in the industry since joining Westinghouse, Church, Kerr upon his graduation in 1902.

A. P. Thoms (A'16, F'26) formerly first assistant superintendent of the street department of the Commonwealth Edison Company, Chicago, Ill., has been appointed superintendent of the department to fill the vacancy caused by the transfer of D. W. Roper (F'14) to the engineering department.

C. S. Cassidy (A'30) formerly assistant engineer, Johnson and Fletcher, Ltd., Bulawayo, Southern Rhodesia, Africa, and more recently with the Victoria Falls Power Company, Cleveland, South Africa, is now electrical assistant to G. H. Langler & Company, Ltd., Johannesburg, Transvaal, South Africa.

S. N. Alexander (Enrolled Student) Oklahoma City, Okla., has been awarded a fellowship at Massachusetts Institute of Technology for the academic year 1933–34, the award having been made by the Charles A. Coffin Foundation, established by the General Electric Company.

G. M. C. Peacock (A'31) formerly with the Metropolitan-Vickers Electrical Company, Trafford Park, Manchester, England, has recently been appointed publicity engineer to the Hackbridge Electric Construction Company, Ltd., Hersham, Walton-on-Thames, Surrey, England.

Walter C. Smith (A'07, M'26) district engineer for the General Electric Company, San Francisco, Calif., was elected chairman for 1933–34 of the Institute's San Francisco Section, in the balloting which took place in April 1933. Mr. Smith served the past year as vice-chairman of the Section.

Herman Halperin (A'21, M'26) formerly head engineer of the technical division of the street department of the Commonwealth Edison Company, Chicago, Ill., has been appointed cable research engineer in the engineering department of the company.

E. M. Wright (A'20, M'31) assistant engineer, division of hydroelectric and transmission engineering, Pacific Gas and Electric Company, San Francisco, Calif., was elected secretary of the Institute's San Francisco Section for the year 1933–34.

Stanley Rapp (A'21) engineer, the Pacific Telephone and Telegraph Company, San Francisco, Calif., was elected a member of the executive committee of the Institute's San Francisco Section for the year 1933–34.

Philip Nudd (A'32) Hampton, N. H., has received a fellowship for 1933–34 from the Charles A. Coffin Foundation, the work to be carried on in Massachusetts Institute of Technology.

J. E. Hobson (Enrolled Student) Marshall, Ind., has received a fellowship for 1933–34 to California Institute of Technology, the award having been made by the Charles A. Coffin Foundation.

C. I. Bradford (Enrolled Student) Newport, N. J., has received a fellowship from the Charles A. Coffin Foundation for the year 1933–34, the work to be carried on at Ohio State University.

W. J. Warren (Enrolled Student) Arcata, Calif., has received a fellowship for 1933–34 from the Charles A. Coffin Foundation. The work will be carried on at the University of Illinois.

A. M. Bohnert (A'12, M'26) district engineer, Ohio Brass Company, San Francisco, Calif., was elected vice-chairman of the Institute's San Francisco Section for the year 1933–34.

W. A. Hillebrand (A'08, M'13) professor of electrical engineering, University of California, Berkeley, was elected a member of the executive committee of the Institute's San Francisco Section for the year 1933–34.

G. H. HAGAR (A'20, M'26) Pacific Gas and Electric Company, San Francisco, Calif., was elected a member of the executive committee of the Institute's San Francisco Section for the year 1933–34.

L. J. MOORE (A'15, M'31) executive engineer, San Joaquin Light and Power Corp., Fresno, Calif., was elected a member of the executive committee of the Institute's San Francisco Section for the year 1933–34.

Obituary

HENRY H. CUTLER (A'03, M'28) retired manufacturer of electrical apparatus and founder of the Cutler-Hammer Manufacturing Company, died in Miami, Fla., May 20, 1933. He was born in Brookline, Mass., in 1858, and graduated in mechanical engineering from Massachusetts Institute of Technology in 1881. For a year following 1884 he was on the student course of the Thomson-Houston Electric Company at Lynn, Mass., and for 2 years following 1885 was general manager of the Citizens Electric Light and Power Company at Akron, Ohio. For 2 years following 1887, he held a similar position with the Newton Electric Light and Power Company of Newton, Mass., and for 2 years following 1889 was manager of the electrical department of the Newton and Watertown Gas Light Company. After being a manufacturer of electrical street fixtures for 2 years, he organized the Cutler-Hammer Manufacturing Company of Chicago, Ill., in 1893, for the manufacture of electric motor controlling devices. Mr. Cutler served as treasurer of the company until 1896, president until 1898, and upon the reorganization of the company in Milwaukee in the latter year, became general manager and chief engineer, holding this position until 1908 when he became vice-president. He held this position until 1917 when he retired from all business activity. Mr. Cutler had more than 90 patents in electrical control equipment.

NORMAN MCDONALD CRAWFORD (A'03) president of the Sandusky Bay Bridge Company, New York, N. Y., died May 2, 1933. He was born in Philadelphia, Pa., in 1859. Between 1877 and 1898 he was in the motive power department of the Pennsylvania Railroad at Altoona, Pa., during which time he served the first 4 years as an indentured apprentice. Between 1899 and 1900 he was superintendent of the Meriden Electric Railway Company, Conn., and in 1900 became manager of the Rochester Railway Company, Rochester, N. Y., installing the Short system, and in full charge of engineering. In 1901 he was engineer for the Jersey City and Bergen Railroad Company, and also engaged in engineering for the Hartford (Conn.) Street Railway Company. From 1901 to 1906 he was engineer and general manager for the Hartford Street Railway Company. In 1906 he was consulting engineer for the New York, New Haven and Hartford Railway Company, and the following year was tramway expert for a railroad in Great Britain. In 1909 he was vice-president and general manager of the Ohio Electric Railway Company, and in 1912, president of the Mahoning and Shenago Railway Light and Power Company in Ohio. In 1916, he was president of the Reading Transit and Light Company, and was then vice-president of the Columbus (Ohio) Railway Power and Light Company for several years.

HERMAN THEODORE HAUSER (A'32) junior engineer, City of San Francisco, Moccasin power house, Moccasin, Calif., died recently. He was born in 1908 in San Francisco, and received his education at the University of California, receiving the degree of B.S. in E.E. 1931. During the summers of 1928 and 1929, he secured experience of an engineering nature, and during the summers of 1930 and 1931, was responsible for the operation of 100,000 hp of hydraulic machinery of the Pelton impulse type in the Moccasin power house. Since graduation in 1931 he has been junior engineer with the city of San Francisco in connection with the Hetch-Hetchy water supply. He was a member of The American Society of Mechanical Engineers.

LEON H. FRANK (A'15) vice-president and general sales manager, Bull Dog Electric Products Company, Detroit, Mich., died May 28, 1933. He was born at Wheeling, W. Va., in 1877. He gained his first electrical experience in 1903 in the construction of telephone lines in California, and in 1905 took a position as salesman traveling Ohio, West Virginia, and Pennsylvania. In 1906, he joined the organization of the Mutual Electric Machine Company of Wheeling, W. Va., becoming sales manager of that company in 1914, subsequently joining the organization of the Bull Dog Electric Products Company.

Local Meetings

Past Section Meetings

Baltimore

TELEMETERING IN LARGE POWER STATIONS, by M. K. Goldstein; A METHOD OF ANALYZING GOVERNOR PERFORMANCE USING THE OSCILLOGRAPH FOR RECORDING DATA, by J. E. Allen, Penn. Water and Pwr. Co.; MODERN DEVELOPMENTS IN PRECISION TIME KEEPERS, by J. M. Kopper, 3rd, student, Johns Hopkins Univ. Prizes of \$25, \$15, and \$10 were awarded for the presentation of these papers. May 19. Att. 70.

Boston

Annual meeting and entertainment. Election of officers: Prof. W. H. Timbie, chmn.; G. J. Crowdes, vice-chmn.; J. M. Murray, secy.-treas. May 9. Att. 220.

Chicago

THE COMMUNICATION EXHIBIT AT THE CENTURY OF PROGRESS, by John Mills, Bell Tel. Labs., Inc. Election of officers: E. C. Williams, chmn.; D. L. Smith, vice-chmn.; F. A. Rogers, secy.-treas. May 15. Att. 135.

Cincinnati

MEASUREMENT OF MODULATION, by E. C. Ebeling; DESIGN OF SHORT WAVE RECEIVERS, by R. J. Kemper; NEON TUBE ORGAN, by W. E. Kock; LIGHTNING PROTECTION FOR DISTRIBUTION TRANSFORMERS, by W. R. Myers; A NEW A C CONTACTOR DESIGN, by A. J. Sacksteder; A RECORDING TORQUE METER, by C. C. Libby; A STUDY OF THE INVERTER, by Ruben Nathan, students. Joint meeting with Univ. of Cincinnati Branch. Election of officers: L. C. Nowland, chmn.; M. S. Schneider, secy.-treas. May 11. Att. 70.

Cleveland

THE EFFECT OF QUALITY AND INTENSITY OF ARTIFICIAL LIGHT UPON SEEING, by J. R. Anderson, L. B. Moore, J. M. Sigler, and H. A. Green, presented by L. B. Moore; IMPEDANCE CHARACTERISTICS OF ROCHELLE SALT, by W. J. Lattin, students. Joint meeting with Case Sch. of Ap. Sc. Branch. April 20. Att. 150.

Election of officers: R. C. Putnam, chmn.; C. A. Harrington, secy.-treas. PROGRESS THROUGH RESEARCH AND ENGINEERING, by H. P. Charlesworth, pres., A.I.E.E., asst. chief engr., A. T. & T. Co. May 18. Att. 102.

Columbus

ELECTRONS AT WORK AND AT PLAY, by Phillips Thomas, Westinghouse Elec. & Mfg. Co. Election of officers: H. L. Willson, chmn.; A. G. Gibbony, vice-chmn.; J. A. Dawson, secy.; E. E. Dreese, asst. secy. May 19. Att. 250.

Dallas

GOVERNMENT IN BUSINESS, by Nathan Adams, First National Bank. Election of officers: D. H. Levy, Chmn.; E. T. Gunther, secy.-treas. May 15. Att. 108.

Detroit-Ann Arbor

ADVANCES IN LIGHTING, by Prof. H. H. Higbee, Univ. of Mich. May 16. Att. 150.

Houston

CURRENT ECONOMIC TREND, by L. M. Sharrar. Election of officers: J. S. Waters, chmn.; J. B. Burr, secy. May 24. Att. 32.

Ithaca

Election of officers: Prof. B. K. Northrop, chmn.; Prof. L. A. Burckmyer, secy.-treas. Annual dinner meeting. June 2. Att. 11.

Lehigh Valley

MODERN INDUSTRIAL SCIENCE, by Dean Dexter S. Kimball, Cornell Univ. Election of officers: N. S. Hibshman, chmn.; W. A. Skinner, secy. May 19. Att. 120.

Los Angeles

VIBRATION STUDIES OF HYDRO-ELECTRIC UNITS, by J. C. Gaylord, Southern Calif. Edison Co.; THEORIES OF EARTHQUAKES, by M. M. Galbraith, Bureau of Pwr. & Lt.; EARTHQUAKE DAMAGE AND RESTORATION AT SEAL BEACH GENERATING STATION, by J. G. Rollow, Los Angeles Gas & Elec. Co. Dinner. Election of officers: A. P. Hill, chmn.; Fred Garrison, secy. May 9. Att. 137.

Louisville

ALGONQUIN SUBSTATION AND ITS PLACE IN THE LOUISVILLE GAS & ELECTRIC COMPANY'S SYSTEM, by E. D. Wood, Louisville Gas & Elec. Co. April 21. Att. 145.

Election of officers: S. T. Fife, chmn.; W. H.

Mansfield, secy.-treas. Entertainment. May 26. Att. 74.

Madison

Simplified Speed Control for Single Phase Locomotives, by W. Giger, Allis-Chalmers Mfg. Co. May 24. Att. 40.

Memphis

D. J. Conant, Layne & Bowler, Inc., gave a talk on the various features concerning the design of deep well pumps. May 16. Att. 42.

Mexico

The Electronic Valve, Its Present and Future Applications, by W. A. Schulenburg, mgr., A.E.G. Dr. M. S. Vallarta, instructor, M.I.T., described his studies on the cosmic rays. May 25. Att. 57.

Montana

The Non-Metallic Resources of the State of Montana, by F. A. Thomson, Montana Sch. of Mines. May 25. Att. 67.

Election of officers: J. A. Thaler, chmn.; H. Dale Cline, secy.-treas. May 25. Att. 10.

Niagara Frontier

Boulder Canyon—Hoover Dam Development, by W. H. Rogers, Westinghouse Elec. & Mfg. Co. May 19. Att. 80.

Philadelphia

Modern Trends in Electrical Measurements, by I. Melville Stein, Leeds & Northrup Co. Election of officers: P. S. Harkins, chmn.; E. C. Drew, treas.; J. L. MacBurney, secy. May 8. Att. 150.

Portland

A Universal Measuring Instrument for Communication Circuits, by T. B. Wagner; The Effect of Lead Length on Impulse Voltage Measurements, by G. Manke and R. J. Mather, students. Joint meeting with Oregon State Col. Branch. Election of officers: V. B. Wilfley, chmn.; W. Brenton, secy.-treas. May 20. Att. 57.

Rochester

Economics of a Gas Supply to a Community, by A. M. Beebe, Rochester Gas & Elec. Corp. Election of officers: E. G. Eidam, chmn.; L. R. Gillespie, vice-chmn.; Wm. F. Young, secy.-treas. May 18. Att. 50.

St. Louis

The Weston Photronic Cell, by J. C. Leben, Jr., student, Washington Univ.; Behavior of Low Pass Filters With Terminations Other Than Characteristic Impedance, by L. W. Buell, student, Univ. of Missouri. Joint meeting with Washington Univ. and Univ. of Missouri Branches. May 17. Att. 140.

San Francisco

California Earthquakes, by Prof. P. Byerly, Univ. of Calif.; Lessons in Building Design Drawn From the Recent Southern California Earthquake, by Prof. R. E. Davis, Univ. of Calif.; J. G. Rollow, Los Angeles Gas & Elec. Corp., described the damage to their Seal Beach Steam Plant. May 26. Att. 135.

Sharon

Electrification of the Pennsylvania Railroad Between New York and Philadelphia, by J. V. B. Duer, Penn. R.R. May 9. Att. 199.

Spokane

Joint meeting with Washington State College and Univ. of Idaho Branches. May 19. Att. 50.

Election of officers: W. Morgan Allen, chmn.; C. E. Cannon, secy. May 26.

Springfield

Modern Ideas Concerning Magnetism, by Prof. S. R. Williams, Amherst College. May 8. Att. 61.

Toledo

Executive Committee meeting. May 10. Att. 10.

Election of officers: E. H. Howell, chmn.; W. M. Campbell, secy.-treas. May 24. Att. 47.

Utah

A Stroboscopic Device for Measuring Rotary Motion, by W. S. Nishiyama; Measurement of Amplifier Distortion, by R. C. Brown, students. Joint meeting with Univ. of Utah Branch. Election of officers: E. L. Morris, chmn.; W. M. Scott, secy. May 22. Att. 45.

Worcester

Phanatron Rectification, by P. W. Currier, Genl. Elec. Co. May 23. Att. 20.

Past Branch Meetings

Alabama Polytechnic Institute

Discussion. May 11. Att. 20.

University of Arizona

Mine Electrification Problems, by E. W. Fredell, United Verde Co. April 6. Att. 12.

Business meeting. April 27. Att. 5.

University of Arkansas

Converters, by Russell Stone; State Line Plant, Chicago, by H. H. Lewis; Transportation to and From Chicago, by H. Mayhan; Points of Interest in Chicago, by R. Boyd, students. May 8. Att. 26.

Armour Institute of Technology

Radium, and Its Uses, by J. W. Juvinall, student. May 5. Att. 25.

Polytechnic Institute of Brooklyn

Reproduction of Orchestral Music in Auditory Perspective, by Henry Vaiden; Use of Electric Driven Pumps in Pipe Lines, by R. Hampshire; Empirical Equations for the Magnetization Curve, by B. Lippmann, students. Election of officers: H. Vaiden, pres.; R. Hampshire, vice-pres.; B. Hegel, treas.; C. L'Allemand, secy. May 24. Att. 31.

California Institute of Technology

Electrical Engineering in Germany, by J. G. Pleasants, student. Election of officers: W. A. Morgan, chmn.; F. Hebel, vice-chmn.; F. J. McClain, secy.-treas. May 24. Att. 25.

Carnegie Institute of Technology

The Application of Vacuum Tubes to the Control of Industrial Motors, by J. H. Belknap, Westinghouse Elec. & Mfg. Co. May 24. Att. 40.

Clemson Agricultural College

Election of officers: R. J. Green, chmn.; H. B. Shores, vice-chmn.; D. E. Penney, secy. May 20. Att. 63.

Colorado Agricultural College

Cosmic Rays, by C. Shields, student. May 8; Att. 8.

Election of officers: Carl Schock, pres.; H. Kahm, vice-pres. May 11. Att. 12.

University of Detroit

Election of officers: Lawrence Bossman, chmn.; Wm. Milby, vice-pres.; Wm. Adamek, secy.; Irving Gold, treas. May 24. Att. 21.

Duke University

Election of officers: H. W. Atkinson, chmn.; W. Wonsidler, vice-chmn.; R. H. Cline, secy.

University of Florida

Elec. of officers: K. S. Rizk, chmn.; S. B. Waring, vice-chmn.; V. B. Nolan, secy.-treas. May 9. Att. 20.

Georgia School of Technology

Election of officers: T. R. Shockley, chmn.; T. J. Seigler, Jr., vice-chmn.; J. C. Thomeson, Jr., secy.-treas. May 16. Att. 26.

University of Idaho

Economics of Wiring, by H. B. Tinling, Tinling & Powell; Symmetrical Components, by Mr. Lyle; Talk and Demonstration of Ultra Short Wave Radio, by Messrs. Sullivan and Mc-Birney. Joint meeting with Spokane Sec. and Wash. State Col. Branch. May 18. Att. 65.

Election of officers: F. H. Koch, pres.; B. Claggett, vice-pres.; Art Dahl, secy.-treas. May 24. Att. 37

University of Illinois

Election of officers: H. S. Shott, chmn.; W. A. Knight, vice-chmn. May 22. Att. 11.

University of Iowa

Central Station Economics, by W. H. Kleiman, Moline Pwr. Co. May 3. Att. 32.

Vacuum Tubes in a Wider Field, by R. J. Sampson and L. R. Baschnagel, students. May 10. Att. 31.

Film—"Principles of Electrostatics." May 17. Att. 32.

Kansas State College

Patents and Inventions, by Prof. R. G. Kloeffler, counselor. April 20. Att. 80.

Joint meeting with Univ. of Kansas Branch. Papers and entertainment by students. May 4. Att. 120.

Lehigh University

Electric Transmission and Distribution, by H. L. Kneisly, W. S. Barstow Co.; Construction and Functioning of the Continuous Integraph, by A. Cottrell, student. Election of officers: W. W. Kinsinger, pres.; D. C. Bomberger, vice-pres.; K. L. Honeyman, secy.; A. W. Lubbers, treas. May 11. Att. 35.

University of Louisville

Election of officers: W. B. Watkins, chmn.; Mr. Craig, vice-chmn.; J. House, secy.-treas. May 11. Att. 13.

Michigan State College

Zinc and Lead Mines of Kansas, by J. S. Schewich, student. Election of officers: J. A. Rankin, chmn.; G. J. TeWinkle, vice-chmn.; W. A. Doidge, secy.-treas. May 11. Att. 25.

Inspection trip to the new bank building in Lansing. May 15. Att. 15.

University of Michigan

Election of officers: W. H. Powers, chmn.; J. F. Crouter, vice-chmn.; A. S. Bassette, secy.; G. C. Morris, treas. May 18. Att. 42.

University of Minnesota

Inspection trip through the Western Union Telegraph Co. May 15. Att. 20.

Election of officers: I. S. Pearson, chmn.; R. W. Qualley, vice-chmn.; Wm. T. Hartman, secy.-treas. May 26. Att. 32.

Mississippi State College

Election of officers: F. G. Marble, chmn.; P. L. Hughes, vice-chmn. May 18. Att. 29.

University of Missouri

Election of officers: Howard Goldrich, chmn.; Dean Harvey, secy.-treas. May 31. Att. 31.

Montana State College

The Battle of the Alchemists, by L. K. Ambrose; Electrical Equipment for Santa Fe 900-hp Rail Car, by H. R. Archibald; Vacuum Tube Construction, by R. V. Bauer, students. May 11. Att. 50.

Election of officers: F. B. Liquin, Chmn.; J. A. White, vice-chmn.; D. C. Shevalier, secy.-treas. Cosmic Rays—What Physicists Have Learned About Them, by C. L. Grebe; Electronic Devices for Industrial Control, by R. Wyman, students. May 18. Att. 49.

Picnic. May 25. Att. 31.

The Range Finder, by D. A. Nauck; Electrostatic Precipitation, by C. Schmitz; Equipment for Electrical Precipitation, by O. Johnston; Radio Telephone for Harbor Craft, by B. Roberts, students. May 25. Att. 46.

Protection of Life and Property Against Lightning, by J. W. Cromer; First All Welded Penstock Completed, by L. A. Eisele; Television Thesis, by T. Degenhart and J. G. Lightfoot; Public Utilities, by J. M. Joyce; Radio and Acoustics, by T. Degenhart, students. June 1. Att. 44.

Newark College of Engineering

Experiences as a Consulting Engineer, by J. G. Berger. Election of officers: A. E. Day, pres.; H. J. Young, vice-pres.; S. C. Greidanus, treas. May 15. Att. 24.

University of New Hampshire

Flashover Tests on 26 Kv Wooden Poles, by A. E. Dogan; Electronic Control, by J. R. Jarest, students. May 6. Att. 21.

Test and Testing Methods, by T. Morong, student. May 27. Att. 31.

University of New Mexico

Electrical show. May 2. Att. 81.

New York University

Discussion. May 5. Att. 20.

Cosmic Rays, by John Lieb; Muscle Shoals, by O. Heister; Meter Testing, by E. Och; Power Plants in Large Hotels, by W. Ramsey, students. May 19. Att. 21.

North Carolina State College

The Tennessee Valley Electrification Proj-

ECT, by J. Bolen, student. Short talks by C. M. Smith, L. G. Atkinson, J. F. Abernathy, students. May 16. Att. 42.

University of North Carolina

The Shoshone Irrigation Development, by R. T. Burnett; The Early History of the Incandescent Lamp, by W. G. Miller; The Application of Relays to Transmission and Distribution Circuits, by J. E. Hunter, students. Election of officers: C. M. Garrison, pres.; J. P. Irvin, vice-pres.; S. H. Usry, secy.; H. F. Stewart, treas. May 2. Att. 30.

North Dakota State College

Election of officers: V. Buck, pres.; K. Hansen, vice-pres.; O. Woodward, secy.-treas. May 18. Att. 9.

University of Notre Dame

Seniors, by Michael Leding, student. Election of officers: Wm. Fromm, chmn.; M. Saleh, vice-chmn.; John Land, secy.; C. Mueller, treas. May 10. Att. 43.

Audible Light, by J. B. Taylor, Genl. Elec. Co. May 16. Att. 550.

Oklahoma A. & M. College

Modern High Quality Welding, by G. Raymond, Am. Tank & Equip. Co. April 24. Att. 70.

University of Oklahoma

Type 11 Western Electric Manual Switching Equipment, by G. H. Humphreys, student. Election of officers: E. F. McMullin, pres.; Ray Pool, vice-pres.; J. E. Graham, secy.-treas. May 11. Att. 21.

Mercury Arc Rectifiers: Their Use in Conjunction With Commutatorless Motors, by J. Hollis, Okla. A. & M. Col.; An Electric Timer, by A. Challener, Univ. of Okla.; Surge Proof Distribution Transformers, by J. R. Jones, Okla. A. & M. Col.; Five Meter Field Intensity Measurements, by Bryan Cole, Univ. of Okla.; The Engineers Sign at Norman, by John Bender, Univ. of Okla.; Findings of Graduate Research on Rural Line Design Investigations, by B. E. Lowe, Okla. A. & M. Col. Joint meeting of Univ. of Okla. and Okla. A. & M. Col. Branches. May 19. Att. 100.

Oregon State College

The Holding Company Situation, by S. E. Skelley, Pacific Pwr. & Lt. Co. May 4. Att. 56.

Election of officers: E. J. Harrington, pres.; R. Gallagher, vice-pres.; K. M. Klein, secy.; R. H. Thielemann, treas. May 5.

A Universal Measuring Instrument for Communication Circuits, by T. Wagner; The Effect of the Lead Length on Impulse Voltage Measurements, by G. Manke and John Mather, students. Joint meeting with Portland Sec. May 20. Att. 65.

Pennsylvania State College

Inspection trip through the power plant of the Pennsylvania State College and the substation of the West Penn. Pwr. Co. May 20. Att. 17.

University of Pennsylvania

Election of officers: R. L. Reitinger, chmn.; C. T. Gohn, vice-chmn.; J. A. Osterlund, secy.; F. P. Caporale, treas. May 9. Att. 11.

Pratt Institute

Sixth annual convention under the auspices of the Wohler Chemical Society, A.S.M.E., and A.I.E.E. Branches, at which several papers were presented by students. Guest speakers A. A. Adler, consulting mechanical engr. and J. V. N. Dorr, pres., A.I.Ch.E. April 19. Att. 520.

The Salinity Process, by W. E. Brown, student; The Old and New Processes of Making Sound, by J. S. Keeler, student. Election of officers: P. C. Krumm, chmn.; C. K. Cunningham, vice-chmn.; J. H. O'Brien, secy.; H. S. Kelly, treas. May 8. Att. 45.

Rhode Island State College

Election of officers: A. E. Kent, pres.; G. Durfee, vice-pres.; F. Walton Perry, secy.-treas. May 3. Att. 10.

Rutgers University

The Interconnection of Power Systems, by L. F. Gehlhaus, student. Election of officers: L. M. Leeds, pres.; R. W. Davis, secy.-treas. May 16. Att. 21.

University of Porto Rico

Election of officers: R. P. Valls, chmn.; H. Sanchez, vice-chmn.; J. E. Bengea, secy.; R. Morales, treas. May 8. Att. 24.

University of South Carolina

Light, by Roy Palmer, Southern Utilities. May 8. Att. 168.

Illumination, by E. L. Willis; A Short History of Light, by D. C. Wilson; Things That Electricity Have Made Possible, by G. W. Arranta, students. The Engineer's Duty to the Public and to Himself, by Prof. T. F. Ball, counselor. May 22. Att. 30.

South Dakota State School of Mines

George Welch elected chairman. May 17. Att. 31.

University of South Dakota

Election of officers: Edwin Nelson, chmn.; Raymond Johnson, vice-chmn.; Kenneth Peterson, secy.-treas. May 24. Att. 10.

Southern Methodist University

Election of officers: J. Bowles, chmn.; R. L. Allen, vice-chmn.; N. Blankenship, secy.-treas. May 26. Att. 17.

Syracuse University

Systems of Speed Control Requiring Auxiliary Commutating Machines, by C. P. Bower; Transil Oil, by J. S. Brzostek; Recent Hydroelectric Developments, by A. H. Carley, students. May 9. Att. 23.

The Effect of Electricity on the Human Body, by H. Kelso; Communication Over a Modulated Light Beam, by C. M. Crysler; Conduction of Electrons Through Space, by A. Adams, students. May 17. Att. 21.

Texas A. & M. College

Prof. N. F. Rode nominated counselor. May 24. Att. 50.

Texas Technological College

Inspection trip through the Tuco power plant of the Texas Utilities Co. April 1. Att. 72.

Properties and Organization of the Anaconda Copper Co., by John L. King, student. Election of officers: W. Gray, chmn.; N. Davidson, vice-chmn.; W. Kelton, secy.-treas. May 2. Att. 11.

Inspection trip through the Bell Telephone Co. May 16. Att. 22.

University of Utah

Election of officers: B. J. Greulich, chmn.; W. Stuart, vice-chmn.; H. F. Greene, secy. May 16. Att. 24.

The Stroboscope, by W. S. Nishiyama, student; Filters, by R. C. Brown, student. May 22. Att. 28.

University of Vermont

Cosmic Rays, by G. P. Osgood, student. Election of officers: G. W. Patterson, chmn.; D. C. Whitney, vice-chmn.; J. C. Arnold, secy.-treas. May 8. Att. 14.

Virginia Polytechnic Institute

The Oberhasli Hydroelectric Development, by E. F. Farley; Electrical Curiosities, by J. E. Hamm; Circuit Breaker Contacts and Arc Extinction, by E. W. Whitmer, students. Election of officers: M. D. Lockwood, chmn.; S. L. Butler, vice-chmn.; L. S. Bell, secy. May 11. Att. 27.

Making Rubber by Electricity, by E. W. Seay; Transoceanic Radio Communication, by H. E. Naylor; Opening Mine Doors by Photoelectric Cells, by J. P. Gills, students. May 18. Att. 27.

University of Virginia

The Chicago World's Fair, by J. L. Stipe; Evils of an Electric Company, by D. Kendall; A Demonstration of Network Relays, by Wm. Dunnington, students. Election of officers: Wm. Dunnington, chmn.; Ellis Conn, vice-chmn.; E. R. Follin, secy.; C. E. Stahl, treas. May 9. Att. 13.

Washington University

Election of officers: Paul Crowley, chmn.; Jacob Levin, secy.-treas. May 15. Att. 20.

Worcester Polytechnic Institute

Election of officers: G. A. Stevens, chmn.; B. H. Colby, vice-chmn.; C. A. Hedlar, secy.; H. E. Stockwell, treas. May 19. Att. 60.

Employment Notes

Of the Engineering Societies Employment Service

Men Available

Construction

GRAD E.E., 35, single, 6 yrs pwr plant elec operation, both hydro and steam. Dispatching and system operation; inspection. Five yrs' cost acctg. Desires position with util, engg or constrn concern. Location immaterial. Available immediately. C-7796

Design and Development

DISTRIBUTION ENGR, around 30, grad, thoroughly exp, 8 yrs in designing and estimating costs of overhead and underground extensions and revamping. Also experienced in underground 4 wire-3 phase network distr system and customer's 4-kv vaults and 11-kv substations. Can furnish best references. D-2167

ELEC HEATING, E.E. with 6 yrs exp in design of elec heaters, control equip, ovens, conveyors. Also estimating, shop and field erection, and contracting experience. Would be especially valuable man to promote all types of elec heating for util. B-9029

E.E. GRAD, 28, married, desires position in design and devpmt or teaching. One yr Westinghouse student course; 6 mos Westinghouse design school; 1½ yrs design of fractional hp motors; 2½ yrs design of industrial motors. Available at once. Location, U.S. C-5051

Draftsmen

E.E. AND DRAFTSMAN, 20 yrs exp, central and substations, distr, industrial plants, pwr and ltg all types of bldgs, marine and RR work. A good man on illumination. Desires position in office, drafting room or field. Has some sales experience. D-2195

GRAD ENGR, 29, married, large physique; 3½ yrs valuation with utilities commission. Two yrs municipal elec devpmt and genl consulting engg. Two yrs elec meterman. Other util experience totals 2½ yrs. Studying accountancy. Aptitude for investigations and reports. Neat draftsman. Adaptable. Location open. C-6381

Executives

YOUNG E.E. with unusual exec and research exp. Available for employment. D-1804

SWBD engr, col grad, 15 yrs experience as swbd engr with large mfg co. Wide experience in mfg co; selection, application of all apparatus going into elec service; actual experience in making, checking wiring diagrams, drawing room methods, as shop contact man, checking, inspecting, estimating and project work. Util exp. D-2166

SOUND REPRODUCTION—after exp as electrician, mech, radio serv, grad Pratt, I.E.E. '28, spent yr pwr house constrn electrician, drafting; spec. serv, installation, sound picture equip U.S.A., later ch engr 3½ yrs Austrialian subsidiary, controlling mfr, test, survey, inst., repairs, serv, advtg, of sound, pwr, projection equip. N. Y., married, schooled Spanish, German. Location immaterial. D-2118

M.A.Sc., Univ of Toronto. Engr with considerable exp in ltg protection, dampening of mech vibrations, inductive coordination, plant design, swbd layout, surveying and motion picture photography with Ontario Hydro. Experienced in handling men. Speaks, reads, writes French and Russian. Best references. Married. Available at once. C-7646

E.E., B.S. in E.E. and E.E., Sigma Xi. Twenty yr practice foremost engg firm, responsible elec work large number steam and hydro stations and

ENGINEERING SOCIETIES EMPLOYMENT SERVICE

57 Post St.
San Francisco

205 West Wacker Drive
Chicago

31 West 39th St.
New York

MAINTAINED by the national societies of civil, mining, mechanical, and electrical engineers, in cooperation with the Western Society of Engineers, Chicago, and the Engineers' Club of San Francisco. An inquiry addressed to any of the three offices will bring full information concerning the services of this bureau.

Men Available.—Brief announcements will be published without charge, repeated only upon specific request and after one month's interval. Names and records remain on file for three months; renewable upon request. Send announcements direct to Employment Service, 31 West 39th Street, New York, N. Y., to arrive not later than the fifteenth of the month.

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industrial plants, some most important in country. Co-author books, author papers and articles. Desires position with engg firm, mfr, util or educational inst. Available now. B-1088

ENGR, qualified to direct all activities of util operating or design divisions. Familiar with the necessary organization and equip for economical operation, maintenance, devpmt and constrn. Location immaterial. Available at once. Twelve yrs operating and util experience. Married, age 35. C-4734

LOWELL INST. GRAD, 30, single. Seven yrs experience with elec mfg concern, (2 yrs, assembling, 5 yrs testing), 2 yrs elec lab. Desires position in elec field, preferably as asst to elec or mech engr. References furnished. D-2217

E.E., 44, available now for design, investigation or consultation work to banking, investment or holding co interested in util and large industrial properties. Eighteen yrs of varied experience in operation, mfg, design, evaluation, investigation and consultation activities. Thorough understanding of engg, financial and commercial aspects. A-535

RESPONSIBLE YOUNG MAN capable of originating ideas or grasping the ideas of others quickly, desires position as asst to busy exec. B.S. in E.E. 1927. Experience includes inspecting and testing work, specification writing, reports, correspondence, etc. Good writer; will consider editorial work. Location immaterial. Available immediately. C-4475

E.E., 47, married, univ grad. Eighteen yrs testing and design exp with the larger mfg cos, mainly on transformers. Eighteen mos design and devpmt on resistance welding machy. Some exp in exec capacity. C-8806

UTIL ENGR, 31, 10 yrs util exp principally with client cos of Elec. Bond and Share, includes design, constrn and operation of transmission and distribution systems, investigations and economic studies, reconstruction and devpmt planning, annual budgets, acctg and genl engg work affecting more economical operation and maintenance of facilities. B-6934

E.E., 42, experienced in commercial research and devpmt, plant engg, mining operations, steel plant pwr generation, distrn and utilization, commercial engg (util), investigations and reports. Salary open, location immaterial, immediately available. B-4905

EXEC OR ASST ELEC ENGR, 32, grad, 10 yrs exp engg, operation, maintenance, constrn, pwr studies and surveys, reports, organization, reorganization, acting elec supt property serving 80,000; responsible charge engg, operation and construction on property including 19 hydro plants and 5,000 miles lines. Location immaterial. B-8904

Instruction

ASST PROF; M.S. in E.E., 10 yrs teaching 3 yrs industrial devpmt and research. At present connected with prominent engg univ teaching E.E subjects and design. Excellent record. C-2893

TEACHER OR ELEC ENGG, 30, B.S. in E.E. deg in 1924. Work almost completed for M.S. deg. Five yrs exp in testing, operation, and distribution engg. Last 4 yrs instructor in E.E. at engg col of a state univ. Desires teaching or engg position. Available July 1. Location immaterial. C-1209

ENGR, B.S., E.E., 1922, married, 33, Westinghouse grad course, 6 yrs sales engg, 4 yrs devpmt engg small intricate apparatus. Will teach physics, mathematics, E.E. Recently completed necessary courses in education and practice teaching to qualify for secondary certificate practically all states except Calif. Location immaterial. Available Sept. 1933 or sooner. B-9863

Junior Engineers

B.S. in E.E., 1930, B.S. in Ed. 1933, single, 28. Two yrs G.E. test including: RR motor and control, a-c and d-c motors and generators, Ind. control, vacuum tube, mercury-arc rectifier and research lab, 2½ yrs teaching experience. D-2163

B.S. in E.E., 1933, N. Y. Univ. Single, 20. Tau Beta Pi. Industrious and energetic. Anxious to obtain any kind of work. Location and salary secondary. Selling, genl business, and some teaching experience. Practical radio work. Any type references. D-2189.

E.E. GRAD, 23, single, B.S. in E.E. '32 from Rice Inst. Has worked in summers during col career, mostly in oil sales and acctg; also exp in seismographic exploring. Will work conscientiously anywhere, preferably in South. A little sales exp. D-2212

E.E. GRAD, 1929, honor student, 26, single. Four yrs instructor in E.E. Desires teaching, lab or tech work. Good references. Available at once. Location, East. D-2200

B.S. in E.E. 1931, Mich Col of Min & Tech, single, 23, Tau Beta Pi. Desires work in any engg field. Experience: 3 mos swbd wiring, 1 mo ltg design, 6 mos surveying and map drawing. Speaks Finnish. Location in North ½ of U.S. preferred. Available at once. D-1650

1931 Grad B.E.E. cooperative course, 26, single. Experience includes elec maintenance, constrn, drafting and lab work. Location immaterial. Available at once. D-1060

E.E.GRAD, 26, 2½ yrs G. E. test and devpmt work, 1 yr hydroelec constrn and test operation. Also has wide knowledge of vacuum tubes and their application. Desires connection with mfg operating or constrn co. Available now. Location immaterial. C-9683

ELEC ENGR, 26, grad Worcester Poly Inst, 4½ yrs experience with large util, handling electrolysis testing of cables in eastern part of country. Familiar with methods of correcting electrolytic action on all underground structures. Good knowledge of underground cable standards and specifications. Working knowledge of elec traction systems. D-1980

E.E. GRAD, 1930. Experience with the Edison Co, testing pwr plant and substation equipment. Valuation engineer and inspector of telegraph apparatus. Desires position where above experience may be useful. D-1838

B.S. in E.E., Communications; Univ of Calif, 1933, 24, married. Desires connection with firm producing equip using grid glow tubes and photo-elec cells. Available now at any location, any living salary. D-2228

B.S. in E.E., 1929; M.S. in E.E., 1933; 28, single, conscientious, industrious. Three and one-half yrs exp, 2 yrs G. E. Co testing, including experimental and devpmt work. Eta Kappa Nu. Desires opportunity in teaching or industry. Available summer or fall. Location immaterial. Please correspond. C-9918

E.E. GRAD B.S. 1933 Wash Univ, St. Louis, 23, single. Earned col tuition. Member Tau Beta Pi, Pi Mu Epsilon. Excellent scholastic record. Good references at col and elsewhere. Qualities of leadership, honesty, reliability. Has knowledge of operational math. Desires work, elec engg. Location immaterial. Salary reasonable, willing to earn it. D-2143

Maintenance and Operation

PWR PLANT AND MAINTENANCE ENGR, extensive exp in swbd, control equip and operation and genl maintenance in large mfg concern. Two yrs as electrician, 2½ yrs as pwr house operator and genl maintenance. Able to assume responsibility. Salary secondary to future. Consider anything. D-2011

PLANT OR MAINTENANCE ENGR, M.E. Cornell, married. Practical experience for 15 yrs in application, maintenance, design and bldg of manual and automatic elecl equip for industrial and central stations together with thorough knowledge of maintenance materials qualifies me for a permanent connection. Salary requirements in line with today's conditions. D-1273

Research

ELEC RESEARCH ENGR, 30, sin le, 5 yrs exp in lab and design work on fractional hp motors. Several special motor constructions invented and studied in design and test. Graduate of Case Sch of Ap Sci, 1925. Now working on advanced deg. Avail 30 days, now employed. D-2165

Sales

IF YOU HAVE A PRODUCT TO SELL THAT IS ECONOMICALLY JUSTIFIED, CAN BE OF VALUE TO YOU, particularly util, industrial, mtg circles. Past 5 yrs tech sales, inaccessible executives hardboiled P.A.'s, cynical engrs, know-it-all supers. Background seasoned exec util engr. Broad exp. Responsibilities eight-million-dollar-annual-expenditure class. Immediate action. C-3963

B.E.E. Ohio State Univ, 32, married, 7½ yrs exp in design of all types and sizes of synchronous motors and low speed alternators with well-known mfrs. Desires position in sales, engg or teaching. Available in 30 days. D-2222

Testing

EXPERT METER MAN, a-c and d-c. Reading, repairing, installing, and calibration of watthr meters. Ten yrs experience with pub util and private concerns. Last position held 5 yrs as ch tester. Age 27 yrs and married. Location of position open. D-2031

Membership

Recommended for Transfer

The board of examiners, at its meeting of June 21, 1933, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Member

Allen, James G., senior engr., Duquesne Lt. Co., Pittsburgh, Pa.
Augustine, Edward T., dist. engr., Western Mass. Cos., Springfield, Mass.
Bivins, Walter T., supt. of pwr. stations, Market St. Ry. Co., San Francisco, Calif.
Brinton, Howard G., engg. dept., Gen. Elec. Co., Pittsfield, Mass.
Buell, Henry H., supt., elec. distribution, Pacific Gas & Elec. Co., San José, Calif.
Clarke, Edith, central station engg. dept., Gen. Elec. Co., Schenectady, N. Y.
Coffin, Harold W., planning engr., Bangor Hydro-electric Co., Bangor, Me.
Craig, Arthur B., meter engr., Edison Elec. Ill. Co. of Boston, Boston, Mass.
Crowell, Robinson, supt., elec. meter dept., Pacific Gas & Elec. Co., Oakland, Calif.
Dallye, Frederick R., sales engr., Alum. Co. of Am., Pittsburgh, Pa.
Dellinger, Floyd E., overhead elec. engr., Los Angeles Gas & Elec. Corp., Los Angeles, Calif.
Gundlach, Wm. E., chief elec. engr., the Milwaukee Elec. Ry. & Lt. Co., Milwaukee, Wis.
Hiltebeitel, Jesse, asst. director of field supervision, City Work Bureau, New York.
Hopkins, Robert H., telephone engr., Am. Tel. & Tel. Co., New York.

Joslin, Arba V., asst. engr., Pacific Gas & Elec. Co., San Francisco, Calif.
Kerchner, Russell M., assoc. prof. of elec. engg., Kansas St. Col., Manhattan.
McKay, Marshall C., asst. engr., gen. constr., Pacific Gas & Elec. Co., San Francisco, Calif.
Meyer, Frank T., equip. engr., Bell Tel. Labs., Inc., New York.
Schilling, Eugene W., asst. prof. of E.E., Michigan Col. of Min. & Tech., Houghton.
Sloan, Thomas S., div. mgr., Georgia Pwr. Co., Rome, Ga.
Smith, Kilburn M., planning engr., Commonwealth Edison Co., Chicago, Ill.
Steele, Elijah H., engr., line constr., Pacific Gas & Elec. Co., San Francisco, Calif.
Speer, Guy F., underground engr., Milwaukee Elec. Ry. & Lt. Co., Milwaukee, Wis.
Thompson, Joseph S., pres., Pacific Elec. Mfg. Corp., San Francisco, Calif.
Youens, Alfred V., E.E., City of Palo Alto, Calif.

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before July 31, 1933.

Alfriend, J. V., Jr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Briggs, A. F., U.S. Coast & Geodetic Survey, Pt. Arthur, Texas.
Brown, A. H. Jr., Elec. Ry. Presidents Conference Committee, Bklyn., N. Y.
Ciallella, E. A., 24 Patten Place, Newark, N. J.
Corson, E. B., The Watts Regulator Co., Rochester, N. H.
Emerson, A. E., Electrical Research Products Inc., New York, N. Y.
Heffernan, F. J., Westchester County Emergency Wk. Bureau, White Plains, N. Y.
Hughes, A. J., Jr., Fountain Inn, S. C.
Lettieri, M. R., 103 E. Westfield Ave., Roselle Park, N. J.
Levy, C. C., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.
Lingal, H. J., Westinghouse E. & M. Co., E. Pittsburgh, Pa.
Martin, H. G., Jr. (Member), Western Union Tel. Co., New York, N. Y.
Milne, J. (Member), Works Department, City of Toronto, Ontario, Canada.
Sine, C., Woodstock Elec. Lt. & Pr. Co., Woodstock, Va.
Vercesi, A. A., Electric Meter Corp., New York, N. Y.
Wolff, F. E., 422 46th St., Brooklyn, N. Y.
16 Domestic

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the address as it now appears on the Institute records. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Anderson, Geo. H., 131 Wenonah Road, Longmeadow, Mass.
Biavati, Jos. D., 22162—91st Rd., Queens Village, N. Y.
Buel, Kenneth, F., 4621 Westminster Pl., St. Louis, Mo.
Cannizzo, Mario, Trumbull-Vanderpoel Elec. Co., Bantam, Conn.
Danstedt, R. T., Y. M. C. A. Col. of Engg., 2200 Prospect Ave., Cleveland, Ohio.
Durant, Wm. T., 736 Broadway Ave., Regina, Sask., Can.
Harcus, Wilmore C., United Artists Studio, 1041 N. Formosa Ave., Hollywood, Calif.
Hottle, Warren M., 437 Hansberry St., Philadelphia, Pa.
Johansen, Harold C., 119 E. 10th St., Marion, Ind.
Kubota, K., c/o Japanese Ass'n of N. Y., 1819 Broadway, New York, N. Y.
Martin, Peter E., 1055 Springhill Ave., Mobile, Ala.
Moore, Everett, 2479 Kalakawa Ave., Honolulu, T. H.
Nelson, Forrest S., 63 Boyd St., Worcester, Mass.
Parker, Ray H., 5355 Poinsette Ave., Richmond, Calif.
Pedersen, P. R., c/o Sanderson & Porter, 52 William St., New York, N. Y.
Stewart, Jenner M., General Delivery, Jackson, Mass.
Victors, Peter, 420 Presidio Ave., San Francisco, Calif.
Walters, Louis G., c/o Y. M. C. A., Portland, Ore.

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, during May are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

AIRCRAFT YEAR BOOK for 1933. Compiled by Aeronautical Chamber of Commerce. N. Y., D. Van Nostrand Co., 1933. 506 p., illus., 9x6 in., cloth, $6.00. An extensive review of the developments of the past year, covering commercial, manufacturing and engineering progress, occupies the major portion of the book. The present records of all kinds are given in full, as well as much statistical data upon production, sales, operations, etc. There is also an aeronautical directory.

ARC-WELDED STEEL FRAME STRUCTURES. By G. D. Fish. N. Y. and Lon., McGraw-Hill Book Co., 1933. 401 p., illus., 9x6 in., cloth, $5.00. The first chapter gives an interesting illustrated review of welded buildings and bridges to date. The next 3 chapters discuss the arc-welding process, weld forms, the physical properties of welds, and stress analysis. Succeeding chapters are upon joint design, economy, construction methods, cost, estimating, shop drawings, and supervision. A valuable final chapter gives critical comment upon some existing structures.

BONBRIGHT SURVEY of ELECTRIC POWER and LIGHT COMPANIES of the UNITED STATES. 9th ed., Oct. 1932. N. Y., McGraw-Hill Pub. Co., 1932. 184 p., illus., 11x9 in., paper, $10.00. This directory lists the electric light and power services in places of 2,500 population or larger, the holding corporations of the country and their subsidiary companies. Financial data are given for each company, including gross and net earnings, funded debt, capital stock and interest charges. Revised to October, 1932.

CONDUCTION of ELECTRICITY through GASES. Vol. 2. By J. J. Thomson and G. P. Thomson. 3rd ed. Cambridge (Eng.) Univ. Press; N. Y., Macmillan Co., 1933. 608 p., illus., 9x6 in., cloth, $6.50. This, the concluding volume of the third edition of this classic work, deals with ionization by collision and by X rays, and with the properties of the electric discharge in all its forms, glow, spark, and arc. Practically rewritten and consists almost entirely of new material.

ELEMENTS of INDUSTRIAL HEAT. Vol. 1. By J. A. Randall and J. W. Gillon. N. Y., John Wiley & Sons, 1933. 261 p., illus., 9x6 in., cloth, $2.75. The fundamentals of heat engineering are presented with a minimum of mathematical discussion and in as simple language as the subject will permit. The fundamental concepts, calorimetry, expansion and changes of state caused by heat, heat transmission, fuels and combustion, air and humidity are discussed, also the elements of thermodynamics. Adapted to home study, as well as class use.

EXPERIMENTAL ATOMIC PHYSICS. By G. P. Harnwell and J. J. Livingood. N. Y. and Lond., McGraw-Hill Book Co., 1933. 472 p., illus., 9x6 in., cloth, $5.00. In this introduction to atomic physics, the object has been to develop logically the theories of radiation and matter, with particular attention to fundamental conceptions and their experimental foundations. Based upon a course given to seniors and first-year graduate students at Princeton University.

HIGH-FREQUENCY MEASUREMENTS. By A. Hund. N. Y. and Lond., McGraw-Hill Book Co., 1933. 491 p., illus., 9x6 in., cloth, $5.00. A description of high-frequency phenomena applied to measurements, suited to the needs of research workers. The principles and methods of measurement are described in detail and discussed critically, the limitations of various methods being pointed out. A new, up-to-date work.

INTRODUCTION to THEORETICAL PHYSICS. 5 vols. By M. Planck, translated by H. L. Brose. Lond. and N. Y., Macmillan & Co., 1932–3, illus., 9x5 in., cloth. Vol. I. GENERAL MECHANICS. 272 p., $2.50. Vol. 2. MECHANICS of DEFORMABLE BODIES. 234 p., $2.50. Vol. 3. THEORY of ELECTRICITY and MAGNETISM. 247 p., $2.50. Vol. 4. THEORY of LIGHT. 216 p., $2.50. Vol. 5. THEORY of HEAT. 301 p., $2.75. This course in theoretical physics is intended for mature students, acquainted with analytic geometry and the infinitesimal calculus, and aims to prepare them for the exhaustive treatises and the detailed special literature.

LASTING PROSPERITY. By A. G. McGregor. Lond. and N. Y., Isaac Pitman & Sons, 1933. 151 p., charts, 9x6 in., cloth, $2.25. According to Mr. McGregor, this work discloses what are bound to be the future currency system and the future international system of the world and outlines the machinery required for their operation. A currency of constant purchasing power would result, and the solution of internal and external economic problems, including the liquidation of war debts, would be greatly simplified. In addition, a policy for foreign investments is presented. The author is an American engineer residing in London.

PRINCIPLES of RADIO COMMUNICATION. By J. H. Morecroft, assisted by A. Pinto and W. A. Curry. 3rd ed. N. Y., John Wiley & Sons, 1933. 1084 p., illus., 10x6 in., cloth, $7.50. During the 5 yr. that have elapsed since the previous edition of this well-known textbook appeared, many changes have occurred in radio practice. These changes are reflected in this new edition. More information is given on rectifying apparatus and circuits, filters, shielding, and electrolytic condensers. The newer tubes are noticed and the action of pieza-active quartz is explained. Throughout the text much new material has been introduced, and obsolete data have been deleted.

PROFIT ENGINEERING. By C. E. Knoeppel and others. N. Y. and Lond., McGraw-Hill Book Co., 1933. 326 p., illus., 9x6 in., cloth, $3.00. The theme of this book is that a business, to remain solvent, must make profits, rather than volume, its goal. To accomplish this sales income and cost outgo must be planned and controlled, as production is. The author presents a plan for doing this and explains the use of his "profitgraph."

RECENT SOCIAL TRENDS MONOGRAPHS. N. Y., McGraw-Hill Book Co., 1933. 9x6 in., cloth. AMERICANS at PLAY. By J. F. Steiner. 201 p., $2.50. ARTS in AMERICAN LIFE. By F. P. Keppel and R. L. Duffus. 227 p., $2.50. METROPOLITAN COMMUNITY. By R. D. McKenzie. 352 p., $3.50. PROBLEMS of EDUCATION in the UNITED STATES. By C. H. Judd. RURAL SOCIAL TRENDS. By E. S. Brunner and J. H. Kolb. 386 p., $4.00. TRENDS in PUBLIC ADMINISTRATION. By L. D. White. 365 p., $4.00. The report on "Recent Social Trends in the United States," recently issued by the President's Research Committee, is supplemented in various directions by these 6 monographs. They record, in extended and detailed form, the scientific and statistical data assembled for the committee and discuss the findings more fully.

BINARY LOGARITHMS. By G. H. Pohland. Chicago, G. H. Pohland, 1931. 24 p., tables, 12x9 in., paper, $2.00. Binary logarithms, with the number 2 as the base, offer a ready means of determining the geometric interval separating 2 frequencies or wave lengths in terms of octaves and decimal fractions of the octave, and hence are useful in the study of electromagnetic phenomena and the design of musical instruments. This mimeographed pamphlet contains 10-place binary logarithms of the first 1,024 integers, binary antilogarithms, 5-place binary logarithms for musical constants and other tables, together with explanatory text.

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A collection of modern technical books is available to any member residing in North America at a rental rate of five cents per day per volume, plus transportation charges.

Many other services are obtainable and an inquiry to the director of the library will bring information concerning them.

Industrial Notes

Bristol Co. Moves Local Quarters.—The Bristol Co., Waterbury, Conn., makers of indicating, recording, and controlling instruments, announces that the New York office is now located in the Daily News Building, 220 East 42nd St. C. N. Williamson, district manager, continues in charge, assisted by a staff of six application and service engineers.

New Watthour Demand Meters.—A new meter which combines in one device a watthour meter and a recording demand meter has been announced by the General Electric Company. The demand mechanism of the new meter, which has been designated as type DG-1, is of the "block-interval" type, recording on a strip-chart the demand over a definite time interval. A record of line is made on the chart for each interval, with $^1/_8$-inch between these lines for all ratings. A hook or quirk at the end of the ink line definitely indicates the exact value of the demand. In addition, the chart is advanced continuously, so that the slope of the line on the chart gives indication of the variation in magnitude of the load during the time interval. The meters have the characteristics of the type I-16 meter, including high torque and complete temperature compensation for all power factors. The combination of high torque and efficient demand mechanism results in a minimum effect on the watthour meter accuracy, even under light load conditions.

Steel Enclosed Cubicles.—A line of standardized 7.5 kv steel enclosed cubicles, which can be assembled in any desired number of units, has been developed by the Delta-Star Electric Co., Chicago. The manually solenoid or motor operated oil circuit breakers are trip free and operating mechanism interlocks with a hinged door of the disconnecting switch compartment. The bus is located in the top of the compartment which is provided with removable end covers to permit ready connection to future units. The relays, meters, instruments, and control switches are attached to hinged doors, insuring easy access to the wiring and control leads.

Gear-Motors.—Small gear-motors with the characteristics and construction of the latest designs of general purpose motors have been developed by the General Electric Company. The new gear-motors combine the desirable features of light weight, efficient high-speed motor drive with a simple compact reduction gear to give almost any desired speed at the output shaft. Connections to driven machines may be made directly or through the use of gears, belts, or chains. Full access to the gear mechanism is possible by removal of the cover plate. A liberal oil capacity and a complete lubrication system assure long life without frequent attention. These motors are available in two types, both in ratings from one-sixth to three-quarters horsepower inclusive; the concentric shaft type, with speeds from 500 to 98 rpm., and the right angle shaft type, with speeds from 200 down to 11 rpm.

Trade Literature

Automatic Feeder Voltage Regulator.—Bulletin 3021, 4 pp. Describes a new automatic feeder voltage regulator for regulating small capacity feeders of any circuit voltage; single-phase or 3-phase; indoor or outdoor. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Instruments.—Catalog 48, 20 pp. Describes switchboard and panel instruments, round and rectangular patterns. Included are ammeters, voltmeters, wattmeters, frequency meters, power factor meters and milli-ammeters, milli-voltmeters, galvanometers, and others. Roller-Smith Co., 12 Park Pl., New York.

Circuit Breakers.—Bulletin C-1963, 8 pp. Describes two new oil circuit breakers utilizing for the first time condenser bushings on small breakers. Designated as types F-50 and F-100, they are manually or electrically operated and rated for indoor service of 5000, 7500, and 15,000 volts. Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

Testing Instruments.—Bulletin 1360, 4 pp. Describes "Megger" and "Meg" ground testers, showing applications for measuring the resistance to earth of ground connections. Bulletin 1355, 8 pp. Describes "Megger" insulation testing instruments of five different types and forty ranges. James G. Biddle Co., 1211 Arch St., Philadelphia, Pa.

Heating Elements.—Bulletin 30, 4 pp. Describes a complete line of strip heaters—flat metallic tubes in which the heating element is nickel chromium, supported in molded insulators. Harold E. Trent Co., 618 N. 54th St., Philadelphia, Pa.

Metal Coatings.—Bulletin, 20 pp. Describes the equipment and process of spraying (termed "Metallizing") a wide variety of molten metals upon practically any solid base. International Metallizing Association, 214 Provost St., Jersey City, N. J.

Motors.—Bulletin C. 1969, 12 pp. Describes Westinghouse Thermoguard motors and applications. Should the motor windings become dangerously overheated, the motor may be so connected as to give a warning signal or to be disconnected from the line. Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

Radio Alloys.—Booklet, 16 pp. Describes numerous metal alloys used in the manufacture of radio equipment, such as nickel, nickel-silicon, nickel-manganese, etc., for high and low resistance wire, for bright and carbonized strip, for grid, support, filament, rheostat, and potentiometer wire. Driver-Harris Co., Harrison, N. J.

Zinc Plating Process.—Booklet, 48 pp., entitled "Duozinc." Describes an improved zinc plating process, and contains comprehensive and detailed information on the most efficient electrochemical methods of curbing corrosion of steel products. Preparation of the product for plating and the entire plating process are fully covered. E. I. du Pont de Nemours & Co., Inc., R. & H. Chemicals Dept., Wilmington, Del.

Rheostats.—Bulletin 1105. Describes a new ring type, 100-watt rheostat, with fine continuous adjustment and "dead" shaft construction, designed for applications requiring a compact, heavy duty instrument. The rheostat is available in values of resistance from 1 to 10,000 ohms. It will dissipate in free air 100 watts continuously with a temperature rise not exceeding 250°C., which is within the limits specified by Underwriters' Labs. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Trolley Duct Systems.—Bulletin, 8 pp. Describes "Bull Dog Trol-e-Duct," a mobile trolley system for conveying electric current to moving and portable electric devices such as drills, buffers, cranes, etc., and consisting essentially of standardized, self-contained sectional units of steel duct, enclosing insulated busbars which distribute current through trolleys to portable electric tools or other moving "loads." Applications are extensive where continuous assembly lines are in operation and the system is readily adapted to other industries. Bull Dog Electric Products Co., 7610 Jos. Campau Ave., Detroit, Mich.

Lightning Arresters.—Bulletin 346, 120 pp. Describes a complete line of lightning arresters and lightning protective equipment and contains much technical information on the subject of lightning protection in general. Equipment listed includes Crystal Valve lightning arresters for both high and low voltage a-c service and for low voltage d-c service; Crystal Valve tank type arresters; neutral arresters and co-ordinating gaps; Garton-Daniels arresters for low voltage a-c and d-c service and for high voltage d-c railway service; ground testing equipment and ground fittings. Electric Service Supplies Co., 17th & Cambria Sts., Philadelphia, Pa.

Testing Set.—Bulletin 543, 4 pp. Describes L. & N. type U testing set, a portable Wheatstone bridge, specially designed for locating faults in telephone and telegraph cables and other communication circuits. The set is sufficiently accurate and reliable for laboratory measurements. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.